THE JOURNAL OF PROSTHETIC DENTISTRY

Vol. 2 September, 1952 No. 5

THROUGH THE EYES OF THE EDITOR

Ralph H. Boos designates rest position as a diagnostic position and relates centric position to it. Then these positions are related to the horizontal hinge axis of the mandible which he believes to move as a true hinge within the limits of the free-way space. The rest position is established first and the record of centric position is made upon closure to the vertical dimension of occlusion. He stresses the importance of the location of the vertical dimension of rest position because of the fact that the maximum biting force can be delivered at this level of jaw closure.

A simple technique for making centric jaw registrations from rest position is described. This should produce excellent results if the patient is properly conditioned and trained. We wonder, however, if the parallelism or lack of parellelism of the ridges might affect the amount of biting force which the patient will exert. The inherent power of the *muscles* of mastication is not materially reduced with the loss of teeth, yet the power exerted through natural teeth is more than 150 pounds while with artificial teeth it is often less than 40 pounds.

The suggestion is made that the power point and centric relation as indicated by the apex of the Gothic arch tracing do not coincide in 35 per cent of the cases. We wonder if this also might be due to a lack of parallelism of the ridges. We believe it is safer to use the apex of the Gothic arch tracing as the indicator of centric position than to trust the power point as the determining factor. A failure to properly condition the patient could cause an erroneous diagnosis. Certainly, as the author suggests, the existing occlusion should not be relied upon for the determination of centric position.

Lincoln E. Sanders discusses the diagnosis and treatment of temporomandibular joint diseases and emphasizes the importance of an accurate diagnosis. Many physical conditions can cause symptoms similar to those of temporomandibular joint disturbances. Cooperation between the physician and dentist is essential for successful diagnosis and treatment. The use of splints for temporary relief and for diagnostic purposes is sound practice.

The use of laminagrams for diagnosis requires accurate angulation of the x-ray tube and film and a correlated observation as well as a thorough knowledge of the anatomy of the joint. The psychologic treatment of the patient is often as important as the dental treatment.

Louis S. Block has written of the preparation of patients for intermaxillary relation records. Mutual confidence and understanding are essential at this step in denture construction. The dentist must know how to help the patient understand what is being

done, if the essential relaxation is to be obtained. The dentist must be critical of his own efforts but must at the same time be helpful to the patient. A centric relation record is a record of a positional relationship, but it is not purely a mechanical problem. Since the mandibular position depends primarily on muscle tone or muscle contraction, and since centric relation exists when all the controlling muscles are relaxed, the psychologic attitude of the patient must be that of relaxation and confidence. There are many excellent suggestions in this article of means for producing the proper condition of the patient.

Milton B. Jensen shows the relations of muscular tensions and some of the problems of prosthetic dentistry. These points are patricularly helpful in understanding the difficulties encountered in making jaw relation registrations and in understanding the variation in tolerance of dentures by patients. This paper is an excellent source of information about patient psychology. The references will be helpful to those who are interested in studying fundamental psychology in order to make their own interpretations.

Robert H. Killebrew has described a technique for mandibular implant dentures which differs radically from others. He has devised a practical method for measuring the thickness of the soft tissues over the bone. These measurements are used to modify the master cast so as to obtain the bone-side form of the implant. This seems to be slightly less accurate than making this form from an actual impression of the body of the mandible. But it has the distinct advantage of requiring a single operation to expose the bone. The direct impression method necessitates two operations. One operation is required to make the impression of the bone and one to seat the implant. His technique seems more accurate than the radiographic method for determining the bone-side form of the implant. Considerably more judgment and experience are necessary in the radiographic method. The angulation of the roentgenograph is an important factor in the determination of the form of the bone-side form of the implant, and a possible source of error. This seems to be overcome by the method described in this article. The author urges care in the selection of patients for implant dentures, that it be done by a dentist qualified in the field of prosthetics, and in conjunction with a qualified oral surgeon.

Frank H. McKevitt has defined the term vertocclusion which combines the requirements of centric occlusion and vertical dimension. This relationship is said to be constant throughout adult life, but the interalveolar space is subject to change. This change results from changes in bone structure which occur because of various factors. The type of bone present in the jaws will determine the amount of change to a large degree. The importance of locating the occlusal plane correctly cannot be overlooked.

F. W. Craddock and H. F. Symmons have made a quantitative evaluation of the face-bow on the basis of geometric drawings. They conclude that the errors developed by a failure to use the face-bow (which they admit) are too small to be of practical significance. While their experiments seem to support this contention, we suggest that if these small errors are added to other unavoidable small errors, the total amount of error is increased. Certain techniques do not require the use of a face-bow. The Stansbery Denture Tripod adjusted with positional plaster check bites and a fixed vertical separation of the casts does not require a face-bow mounting. It is not of value when flat cusp teeth are used *and* the *vertical separation* of the casts is *not changed* on the articulator. If the vertical separation of the casts is changed on the articulator, the face-bow is important. If cusp teeth are used, it is important in the development of the angulation of cuspal inclines. Errors in the inclines of cusps are most difficult to detect in the mouth, but they are most damaging during denture function. We feel that the face-bow is of value for convenience in mounting, even if it had no value otherwise.

Edwin N. Kime has written an excellent summary of the neural mechanisms which are of impotrance to the prosthodontist. This article with its explanatory tables will fur-

nish explanations for the way patients react to the various devices that are placed in their mouths. The faults of some techniques for denture construction will become apparent as they are analyzed in the light of the anatomy as described in this article.

S. Howard Payne reports on further researches on the efficiency of posterior teeth. Duplicate dentures, except for the posterior teeth, were made for patients. The results of the chewing tests and the subjective observations of the patients indicate the desirability of selecting the posterior teeth according to the mouth conditions. There seems to be merit in this suggestion.

Edwin S. Smyd has described a number of experiments to show what happens when stresses are applied to fixed partial denture restorations. An analysis of the results of these experiments and the application of engineering principles to the problem show the causes of failure of fixed bridges. On the basis of this study, practical suggestions are made about the design of restorations and cavity preparations.

Leo Talkov has described three techniques for making temporary fixed bridges and splints. They are practical and relatively simple to construct. Quick-setting cold acrylics are used with variations in the types of matrices. Since they are formed directly in the mouth, their indication for temporary restorations is apparent.

Jack Buchman has described a means for using a central bearing point and a Gothic arch tracer for establishing the jaw relations when dentures are relined. This is a new approach to a difficult problem. This procedure will overcome one of the most annoying operations in prosthesis. While the procedures are more extensive than those commonly used, the accuracy of the occlusion which is developed makes them worth while. The only difficulty which does not seem to be avoided is that of orienting the dentures in relation to the ridges for esthetics and tooth-ridge relations. No doubt this can be done by careful manipulation of the dentures during the first stage of the impression making.

—Carl O. Boucher

EDITORIAL

Nomenclature

DENTAL nomenclature needs revision. The misunderstanding that has resulted from different interpretations of the same terms has caused utter confusion in the minds of the individual dentists. If this confusion is to be eliminated, there must be agreement on the meaning of terms. Many organizations in dentistry have recognized this need and have attempted to do something about it. They have all been confronted by similar obstacles to agreement on nomenclature. These obstacles arise from three sources: inheritance, geography, and the specialties.

Much of dental nomenclature has been *inherited* from our predecessors in dentistry. Since our profession was born just one hundred-twelve years ago, a new language has been developed. It was developed largely by rugged individualists who worked alone. Their thoughts, concepts, and ideas needed labels, so they coined the terms which meant (to them) what they intended to say. Unfortunately, these pioneers did not agree on the meaning of the terms, so different terms were used to express the same concept. These terms have been handed down to contemporary literature subject to the same variations in interpretation. Many of the terms are still in use even though additional information and research have proved them inadequate. It is no reflection on the leaders of fifty years ago that the nomenclature devised by them is criticized and revised. Any term that is incorrect or inadequate must be eliminated if we are to progress. If long usage is the only virtue of a term, it is insufficient reason for its continued use.

Geography has played an important role as an obstacle to a uniform nomenclature. In contemporary dental literature, various terms which are intended to mean the same thing are used by authors and clinicians. These terms vary with the section of the country in which the authors live. Some progress is noted in this regard as more of the authors attend meetings that are national in scope. There they confer with dentists from other sections of the country, and their colloquial terminology is assimilated nationally or eliminated on its merits.

The various specialties have been obstacles to the revision of dental nomenclature even though the profession as a whole looks to them for guidance. The reason for this is simple. Each specialty is primarily interested in its own problems, so each one uses terms which suit its needs. This is done in many instances without due consideration of the effect such terminology will have on the thinking in the other specialties. The apparent disagreement between the various specialties is not real. It reflects only the differing viewpoints of the various specialties. Unfortunately, these differences in nomenclature result in the confusion and misunderstanding among the readers of contemporary dental literature. A sincere effort by all concerned, together with patience and tolerance, eventually will bring order and logic into dental nomenclature.

—Carl O. Boucher

REPORT OF THE COMMITTEE ON PRINCIPLES, PRACTICES, AND NOMENCLATURE*

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Mean Foundation Plane.—The mean of the inclination of the denture-supporting tissues. Since the tissues constituting the denture foundation are irregular in form and consistency, and since there is only one direction from which force may be applied if it is to comply with the law of requiring "force at right angle to support," the mean foundation plane forms a right angle with the most favorable direction of force.

Foveola Palatina.—Either of two small depressions (pits) in the palatine mucosa on their side of the midline, near the junction of the hard and soft parts of the palate.

Posterior Palatal Seal (Post Dam).—The air seal at the posterior border of a denture.

Rugae Zone.—The ridged anterior portion of the roof of the mouth.

Retromolar Pad.—The soft area of the posterior end of the lower alveolar ridge.

Sublingual Crescent.—The crescent-shaped area on the floor of the mouth following the inner wall of the mandible and tapering toward the molar regions. It is the area sometimes covered by the denture base to produce a valve seal.

Lower Ridge Slope.—The posterior portion of the lower basal seat that turns up to form a forwardly facing incline. The lower molar slope may start abruptly or it may turn up gradually. It may be firm in its entire extent or yielding only in its posterior part. The steepness is apparent on the cast, but the consistency must be learned from examination of the tissues themselves.

Denture Edge.—The extreme verge of the denture base at the buccolabial, lingual, and posterior limits.

Denture Flange.—The buccolabial vertical extension of upper or lower denture base or the lingual vertical extension of the lower one. The buccolabial denture flanges have two surfaces: the buccolabial surface and the basal seat surface. The lower lingual flange also has two surfaces: the basal seat surface and the lingual surface.

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*This report was accepted without objection by the Academy of Denture Prosthetics in New Orleans, March 21, 1952. Any term or definition to which there was any objection whatever has been deleted from the report. This is a sincere effort to solve the problems of prosthetic nomenclature.

Modeling Plastic (Modeling Compound).—Thermoplastic; a composition usually composed of gum dammar and prepared chalk, used especially for making impressions of the basal seating areas. This material is sometimes erroneously called modeling compound, the word "compound" here being incorrect.

Occlusal Plane.—The plane on which the opposing teeth occlude. This is a loose term, because the occlusal surfaces of the teeth seldom lie all on the same plane. However, it is sufficiently accurate in some connections and should be retained.

Working Occlusal Surface.—The part of the occlusal surface of the teeth that meets the opposing surface in jaw closure. It is the surface that accomplishes work during chewing. All or part of the occlusal surface of a tooth may constitute its working occlusal surface, but on right or left side all of the tooth surfaces that accomplish work taken together constitute the working occlusal surface of that side. When the term "occlusal surface" is used, "working occlusal surface" is meant unless otherwise specified.

Working Side.—The side, right or left, toward which the mandible moves in the function of mastication. (See Balancing Side.)

Balancing Occlusal Surface.—The surface that occludes at the opposite extreme of the occlusal scheme from a designated site. For example, when the mandible is protruded to bring the lower incisors even with the upper ones, the contacting parts of the molars are designated as balancing occlusal surfaces.

Balancing Side.—The side opposite the working side. (See Working Side.)

Occlusal Platform.—Any essentially horizontal occlusal surface on an upper or lower posterior tooth or teeth.

Subocclusal Surface.—A surface that faces teeth of the opposite jaw, but does not actually occlude. It is distinguished from the working occlusal surface, which does occlude. Any part of the occlusal surface can be made subocclusal by depressing it.

Unstrained Jaw Relation.—Any relation of the mandible to the maxilla that exists without occlusal force. Under this definition, unstrained jaw relation exists when the mandible is either in or out of centric relation at any degree of opening, so long as there is no strain due to the pressure of occlusion.

Rest Relation.—The relation of the mandible to the maxilla at which there exists in all of the muscles involved a state of balanced tonus.

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OCCLUSION FROM REST POSITION

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THE MAXIMUM intercuspation of teeth provides occlusion which establishes a relation of function between the mandible and the maxilla. This function involves muscle physiology and the temporomandibular joint. The ideal is a balanced occlusion in harmony with muscle forces and with the condylar heads in their normal positions in the glenoid fossae.

When the conditions are normal, a comfortable physiologic relation is established with a normal efficiency. Many cases are presented in which the normal occlusion has been lost. Some of the cases include malocclusion, abrasion, periodontoclasia, loss of teeth, and temporomandibular involvement of various degrees. To treat these cases, it is necessary to re-establish the intermaxillary relation and physiologic function.

The basic diagnosis requires a location of the vertical dimension, centric relation, and the horizontal rotation center of the mandible in order to establish a jaw position for occlusion. Vertical jaw relation involves esthetics, space area for the placement of teeth, leverages, and the amount of force that may be placed upon the occlusion and oral structures.

Centric relation is the position of the jaw toward which the mandibular movements are directed in closing and in mastication. The horizontal rotation center is the position of the mandible when the muscles are of equal balance on both sides, and the condylar heads are in a normal position in the glenoid fossae. The mandible may be tipped up on one side or the other, or up in front or in back by muscle pull in order to accommodate to conditions of the existing occlusion.

Generally our attention has been directed at the existing occlusion, but when we consider the forces which are applied and the relation of the condylar heads in the glenoid fossae as affected by the occlusion, we realize that our problem is basically one of physiology and anatomy.

The natural teeth or the dental restoration maintain the degree of vertical opening and determine the distance at which resistance is met with the contraction of muscles to provide a biting force. Perhaps the most significant factor involved is the musculature. It provides the position and movement of the mandible as well as the forces applied.

Read before the Chicago Dental Society, Chicago, Ill., Feb. 4, 1952.
Received for publication April 18, 1952.

REST POSITION

The neutral center of forces is rest position. Rest position is evident when the mandible is hanging in a free position and is involuntarily suspended by the elevator and depressor muscles as well as the external pterygoid muscle. A review of physiology and anatomy provides the principles involved in the intermaxillary relation.

All muscles have a normal length from their origin to insertion. When muscles are in a tonus of rest, there is a slight function of some of the fibers but no contraction or extension of the muscle as a whole. When neither the elevator nor the depressor muscles nor the external pterygoid muscles are in function, a neutral center rest position of the mandible is assumed.

Over the past number of years, considerable study has been devoted to the rest position. It has been established that there is a rest position of the mandible for every individual, and that it is reasonably constant over a long period of time.

Another most important consideration regarding the muscles is the amount of force which they exert. The important factor of muscle action is that there is a critical length (in the distance from origin to insertion) at which the muscle can exert the greatest force in contraction. When the muscle length is shortened, and the muscles sags, there is less power. When the muscle is extended beyond the critical length there is less power. In extended muscles, there is always a tendency to return to the normal length. This develops a continual tension. The length of the muscles of mastication is changed with the opening and closing of the vertical dimension. The biting force of many patients was measured, and each patient was found to have a maximum biting power at a reasonably constant vertical dimension. When the vertical dimension was closed, there was less power. When the vertical dimension was opened, there was less power, but there was also a continual tension at the extreme opening.

A correlation between the vertical dimension of maximum force and rest position was dictated by the normal length of the muscles, which is indicated for both posititons. Registrations were made of rest position and of maximum force on each patient. It was found that the two positions coincided, which substantiated the physiologic accuracy of the position. This provided a very important correlation, as it is possible to use either maximum force, or rest position, as the basic reference position.

The free-way space, or distance between the teeth at rest and occlusal contact, has been established as normal and essential, and is from 2 to 4 mm. when measured extraorally. This allows approximately 1 to 2 mm. of space between the first molar teeth. The free-way space provides a freedom from tension, because the teeth are not in occlusion when the mandible is at rest. A free-way space must be maintained to avoid continual force on the teeth and their supporting structures.

The small hinge axis movement from the position of rest or maximum force to the position of occlusion (about 2 to 3 mm. in the normal articulation) is evidence of the close relation of position of rest or maximum force to occlusion. The

effort used in mastication and the vertical dimension of maximum force are closely related to the free-way space.

FORCES IN MASTICATION

It is interesting to analyze mastication and the application of force on the teeth. As the bolus of food is placed on the occluding surfaces of the teeth for crushing, the muscle force is directed so as to bring the occlusal surfaces of the teeth into contact. In ideal cases, the maximum force may be exerted when the bolus has been compressed against the occlusal surfaces of the posterior teeth. At this time, the gap between the teeth is approximately 1 to 2 mm. As the teeth are contacted, the force is dispersed or the teeth are only lightly touched.

In those cases where the free-way space has been filled in, there is a contact of the teeth at rest position which creates a continual tension on the muscles of mastication and the teeth. Those cases which have been opened more than to the rest position have the muscles extended when the teeth touch. These patients cannot reach the jaw position of maximum masticating effect, and there is a continual tension within the muscles to return to their normal length. This creates a traumatogenic situation. The teeth and the related structures are under severe tension as the muscles attempt to return to their normal length.

If a dimension extremely short of normal vertical dimension has been established, less force can be exerted on the bolus of food. When the free-way space is too large, most of the muscle fibers have contracted before the bolus of food is compressed. Efficiency in mastication is reduced.

A reduced masticating force may be indicated by the condition of the oral structures, and this may be accomplished by a large free-way space. This evidence indicates that the maximum vertical dimension of occlusion for an individual patient may be established by determining the vertical dimension of rest position or maximum force, and reducing this dimension 2 mm. The maximum opening of the vertical dimension is the rest position or the position of maximum force, minus 2 mm.

If conditions indicate it, the vertical dimension of occlusion may be closed more than 2 mm. from rest position. A free-way space of 3 to 5 mm. or more could be indicated by certain mouth conditions or type of patient. This increase in the free-way space reduces the amount of force which can be placed on the teeth and their supporting structures.

The position of the mandible is a significant factor in the location of the condylar heads in the glenoid fossae. The condylar head is located in the temporomandibular joint, with the meniscus in an anterior and partly superior relation to it (Fig. 1). The meniscus is an avascular disc of fibrocartilage and is a pressure-bearing type of tissue. The tissue posterior and superior to the condylar heads is connective tissue which contains blood vessels and nerves. This tissue will not bear pressure; therefore, when it is under pressure, it may cause the sensation of pain.

When the mandible is at rest position, the anatomic structures around the condylar head seem to be in their normal relationship. Should the condylar head be forced into a distal position by the occlusion, there may be a basis for trauma and pain. A rotation of the mandible may force the condylar head on one side or the other up into a traumatic position which would also cause trauma or pain. A forward position of the condyle usually would be bearing on the meniscus, and would not cause pain, although there is the possibility of injury.

The diagnostic jaw position of maximum muscle force, horizontal rotation center, condylar head position, and free-way space may be obtained by a registration of rest position.

PATIENT CONDITIONING

Before making the registration of rest position, it is very necessary that the patient thoroughly understand what is meant by the rest position of the mandible.

The patient should be comfortably seated in the dental chair with the head and the trunk in a normal, upright position. The chair should be adjusted to the patient, not the patient to the chair. The arms should be resting on the armrests and the feet on the footrest. The legs should not be crossed.

The patient should understand that when the mandible is at rest the teeth are not in contact, and that there is a space between the teeth. The lips may or may not be together, depending upon the comfort of the patient.

After this explanation, the patient should hold the mouth extremely far open for about one-half minute. This is done to extend the muscles and produces a slight fatigue. Relaxation is more easily attained by fully extending the muscles first, then letting them snap back to their normal length. During the movements that follow, the teeth should never be together. There should always be a space between them. Any guiding movement in occlusion must be avoided.

The mandible is moved to the right as far as possible and then relaxed; then to the left as far as possible and relaxed; then protruded, relaxed; retruded, relaxed; and opened and returned to rest position. Each movement is a distinct exercise.

Sometimes it is necessary for the patient to practice a number of times. The exercise may be treated as a prescription, and the patient should continue to repeat the movements a number of times.

When the patient seems to conform to the directions, and a rest position can be detected, it is quite easily registered. A pencil dot is made on the tip of the nose, and another in the vertical line on the chin. With a ruler or a pair of dividers, the distance between these two marks when the mandible is at rest is measured. The measurement is recorded so it can be used for reference.

One may find that some patients have difficulty registering the rest position. Relaxation is very difficult for some patients because of nervous tension or habit patterns. The prescribed exercises should be used by the patient several

times a day for a number of days. It should be suggested that the exercises be repeated two times before retiring, two times after arising, and two times during the day.

Sometimes a habit pattern is presented which is so strong that the various relations during phonetics or swallowing may follow in an incorrect pattern. If a patient does not show a free-way space, and if the occlusion has not been built up, a nervous tension is present. Physiologically, there is always a minimum free-way space present. It is necessary to work with these patients over quite a period of time, during numerous appointments, in order to obtain the necessary relaxation.

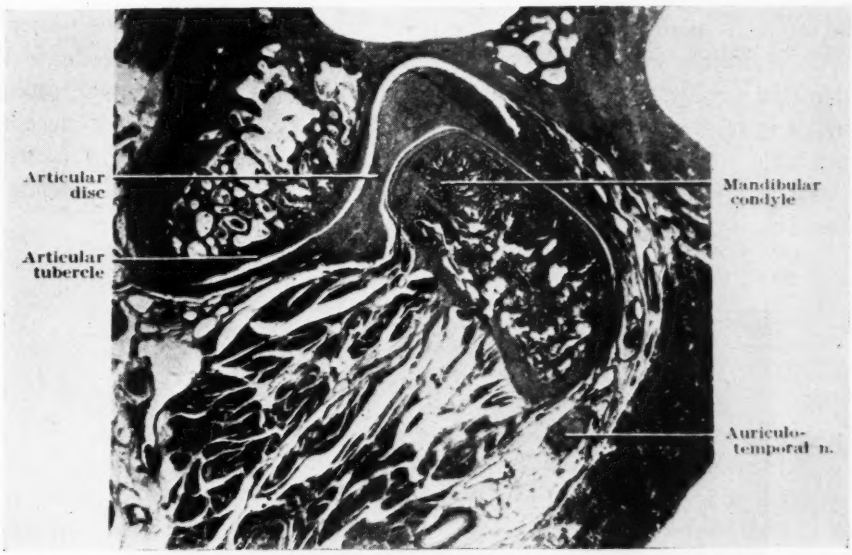

Fig. 1.—Sagittal section through the condyle and the articular fossa. Note the connective tissue posterior and superior to the condyle. (From Sicher, Harry: Oral Anatomy, St. Louis, 1949, The C. V. Mosby Company, p. 159.)

A demonstration of relaxation of the hand, as it hangs down in a free position, is helpful to illustrate relaxation. In severe cases, it may be necessary to use sedatives or hypnotics. Hot packs on the side of the head are helpful for relaxation, particularly in patients with temporomandibular disturbances.

It may take considerable effort and psychology to obtain the necessary cooperation from the patient. It should be kept in mind that there is a rest position for every patient, and that it can be obtained with perseverance. A conditioned patient will provide better registrations for any technique.

After the patient is able to register rest position, he should move the jaw slowly from rest position to occlusion, and the path of closing should be observed. Oftentimes, one will note premature contacts of certain teeth. The mandible may be thrust to the distal, laterally, or protrusively by the occlusion. This is evidence of the cause of the trauma which may be indicated by the conditions presented.

REGISTRATION OF REST POSITION

The rest position transfer registration is made in plaster of Paris. This material was selected because it is readily available, is accurate, and avoids a resistance to closure. The use of a resistant material, such as wax or modeling compound, introduces the application of force for registration. This may record a habit pattern or a force applied unilaterally which would cause a tipping or rotation of the mandible. An unstrained relation provides a neutral center position of the mandible. A good plaster of Paris which sets in from three to five minutes is used for the registration. A plaster gun is found to be very helpful in placing the plaster on the teeth.

The mouth is examined to determine if undercuts are evident in the posterior area. The undercuts are relieved with wax, cement, or cotton to facilitate the removal of the registrations. In patients who have lost teeth and much osseous structure, it is advantageous to build up a stabilized occlusion rim to reduce the space available for the plaster. In edentulous cases, the registration is made on the trial setup on stabilized bases. Petroleum jelly over the teeth facilitates the removal of the plaster record (Fig. 2).

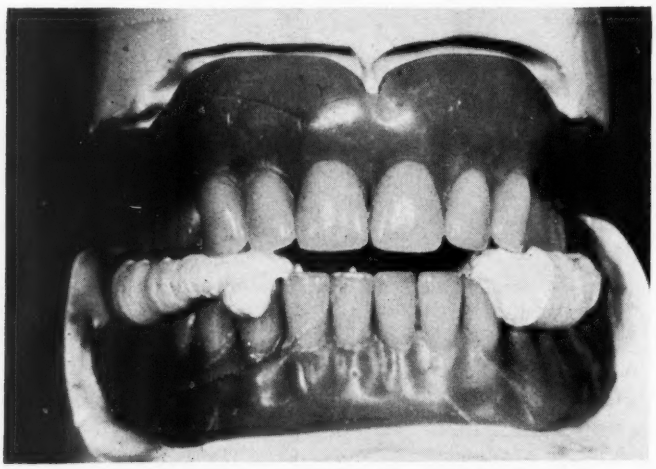

Fig. 2.—Plaster rest registration with the trial setup in an edentulous case.

The patient should be instructed previously and should be thoroughly familiar with rest position. A period of time for conditioning the patient facilitates the registration. The patient is instructed to hold the mouth open while the plaster is mixed and placed in the gun. While the plaster is soft (about the consistency of heavy cream) it is forced out of the plaster gun, and over the occlusal surfaces of the lower posterior teeth or ridge area (Fig. 3). Only the posterior teeth and ridge area should be covered as this is all that is necessary for a transfer.

Immediately after placing the plaster over the teeth, the patient is instructed to bring the mandible to rest position (Fig. 4), and the reference points on the nose and chin are checked. One should not say "bite" or "close," but "come to rest" as this suggests the proper psychologic reaction. The patient is instructed to hold the jaw in rest position until the plaster is thoroughly set.

The patient is then directed to open the mouth and the plaster registration blocks are removed. The excess on the buccal and lingual is cut away, as only the occlusal area of the registration is to be used. Three or more registrations should be made of rest position. Each pair is numbered for proper identification, 1, 2, 3, etc.

Fig. 3.—Injection of plaster of Paris with a plaster gun over the posterior teeth.

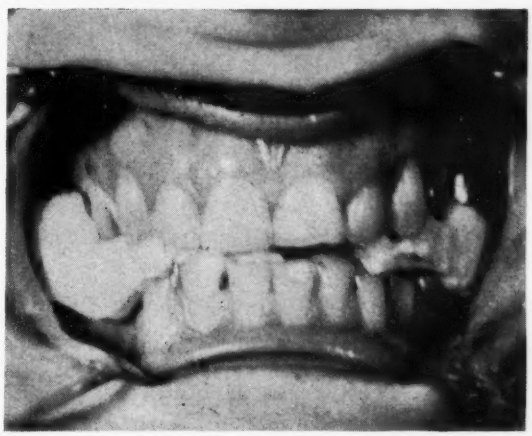

Fig. 4.—Registration of the rest position by plaster of Paris.
Note the plaster is in the posterior area only.

Rest position is free of any occlusal contacts, so it is a free position, and in order to provide a positive check of rest position, it is necessary to have at least two registrations which are identical. The registrations are of the vertical dimension, the centric relation, and the horizontal rotation center.

MANDIBULAR REGISTRATIONS

A face-bow transfer registration is made for mounting the casts. Other methods for cast mounting may be employed which provide an orientation of the casts to the articulator selected. The rest position registration may be included as part of those techniques which require various recordings for lateral and protrusive jaw relations. All of these are most important for a thorough diagnosis. A primary diagnosis may be made from the casts when they are mounted by the plaster rest position registration.

MOUNTING OF THE CASTS

It is necessary that sharp, accurate casts of both the upper and lower jaws be obtained. The plaster registrations are an accurate reproduction of the forms of the natural teeth, and must fit the casts accurately to provide for a correct mounting (Fig. 5).

The anatomic or spherical articulator of individual choice may be used. The first cast is mounted with the aid of a face-bow or mounting jig. The second cast is mounted by seating one pair of the plaster registrations on the first cast and seating the second cast into them. The plaster registrations establish the greatest vertical dimension that will be used, and the articulator is to be closed from that position (Fig. 6). Therefore, it is necessary that the upper member of the articulator be opened above a horizontal position when the mounting is made. The amount opened is about the same as the thickness of the plaster registration.

By having the upper member above a horizontal position, the vertical movement of the arm will be similar to the jaw movement. When the upper arm is below horizontal during the mounting, the closing movement is more rapid at the anterior part of the cast than on the mandible because of the greater distance from the hinged axis. Normally, the movement in the anterior region is usually twice the amount of that in the posterior region. This is because of the difference in the distance from the hinge axis.

At a normal vertical dimension, the mandible has been found to have a hinge axis in the area of the condylar heads. The hinge axis remains at the center point in the condylar heads for from 5 to 9 mm. of the closing movement of the mandible from rest position. The amount of movement in the individual patient may be examined by the use of a face-bow to determine the hinge axis. It is my opinion that rest position is within the limits of the normal hinge movement of the mandible.

Before the plaster registrations used for mounting are removed, dividers are set, and marks are placed on the front of the upper and lower casts. The plaster registrations are then removed, and another pair of registrations tried in position to check the mounted relation. The dividers are placed on the original marks to check the vertical dimension of rest position. This is a positive check on vertical dimension, and centric relation is checked by the seating of the casts in the plaster registrations. A minimum of two registrations must coincide before the position of the casts as mounted can be accepted as correct.

To place the relation of the casts at the *maximum* vertical dimension of occlusion, a mark is placed 2 mm. above the divider mark on the upper cast. The plaster registrations are removed and the articulator is closed that amount (2 mm.) to provide for a study of tooth and jaw relations at the maximum vertical dimension of occlusion. As we observe the intermaxillary relation with the articulator closed 2 mm. from rest position, we may determine the procedure necessary to provide occlusion at this level (Fig. 7).

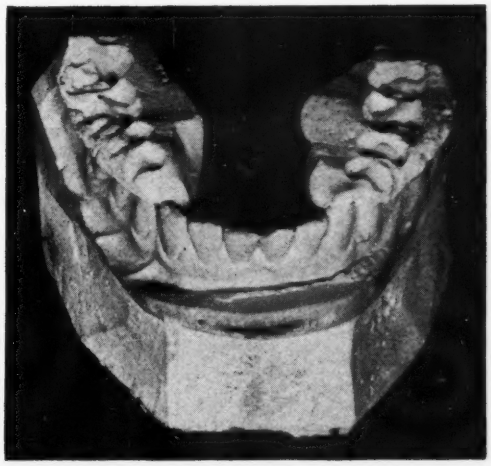

Fig. 5.—Plaster rest registration in place on the lower cast. The excess on the upper surface has been trimmed off.

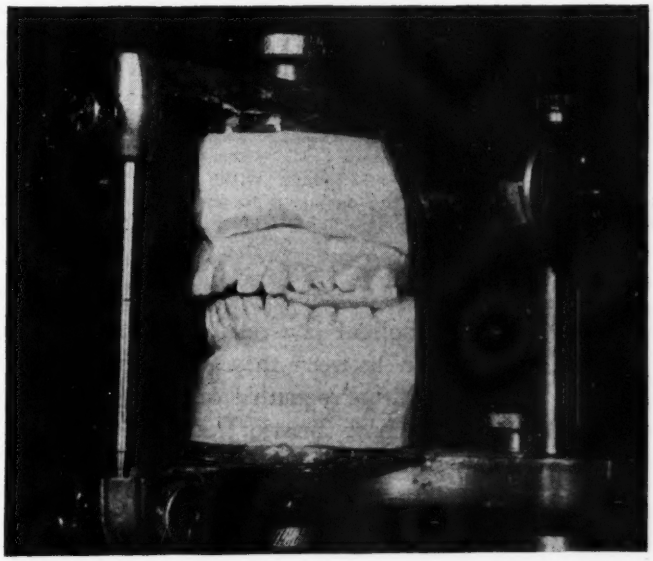

Fig. 6.—The completed rest mounting. The upper arm of the articulator is above horizontal.

Conditions of the teeth and related structures and leverages may indicate a reduced vertical dimension. By closing from rest position, we have a physiologic reference point. The occlusion is free of tension, and the centric and horizontal relations are in harmony with the muscle forces. The condyles are in their normal relations in the glenoid fossae.

A study of the mandibular movements by the patient that are necessary to reach the existing occlusion may be made by mounting the casts on an articulator which will permit a free movement. Many times a lateral thrust is developed after premature contact, and the median lines are off when the teeth are in occlusion. Sometimes the lower anterior teeth contact the lingual surfaces of the upper teeth, and a distal and upward thrust is necessary to bring the posterior teeth into occlusion. The loss of vertical height by shifting of teeth may cause the mandible to tip to reach occlusion. These conditions are often the cause of temporomandibular pain, since they cause the condyles to be forced against the connective tissue distal and superior to them.

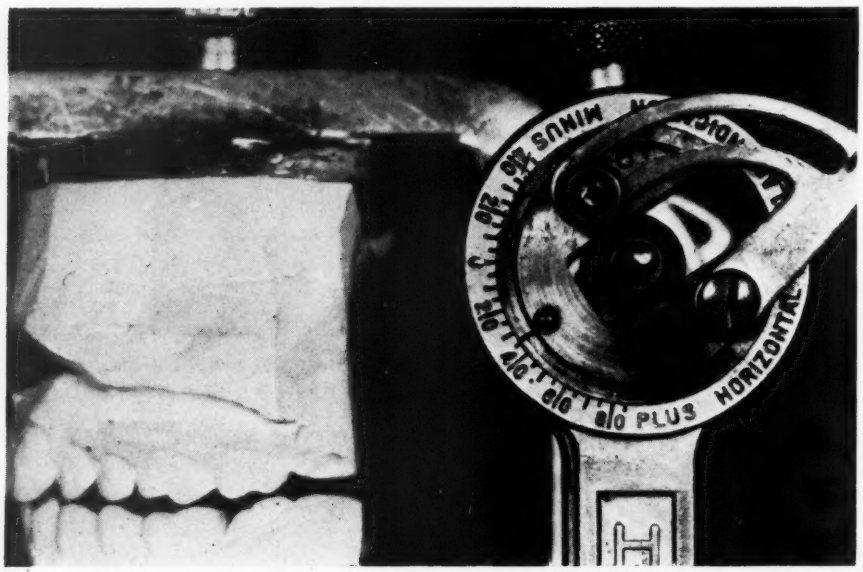

Fig. 7.—Vertical dimension closed 2 mm. with the anterior teeth in contact. Note the need for the reconstruction of the occlusion to provide harmony of the forces of occlusion and the anatomic structures.

The cause of abrasion, tooth movement, and periodontoclasia may be evident by the thrust from the normal jaw relation to the relation dictated by the existing occlusion. A relation between these conditions and the movements of the mandible may be evidenced. Prognathic cases with evidence of abrasion on the labio-incisal third of the upper anterior teeth indicate that the mandible is being forced protrusively from its normal relation.

POSSIBLE PROCEDURES FOR TREATMENT

Treatment planning for adjusting the articulation may be selected from a number of different procedures. Since all of the procedures require an individual study, only a brief summary of the procedures are presented at this time.

The first is that of conditioning the patient. In all cases, the patient should be conditioned for the mandibular movements and the relief of tension by the prescribed exercise as previously suggested. The exercise is particularly helpful in the treatment of temporomandibular joint crepitus or cracking, as well as bruxism. It is also helpful in reducing nervous tension, and relieving tension on the existing occlusion.

The second is orthodontics, which is particularly helpful when it is indicated and when conditions are favorable.

The third is selective grinding. Many cases may be treated and greatly benefited by selective grinding to bring the occlusion into harmony with the muscle forces.

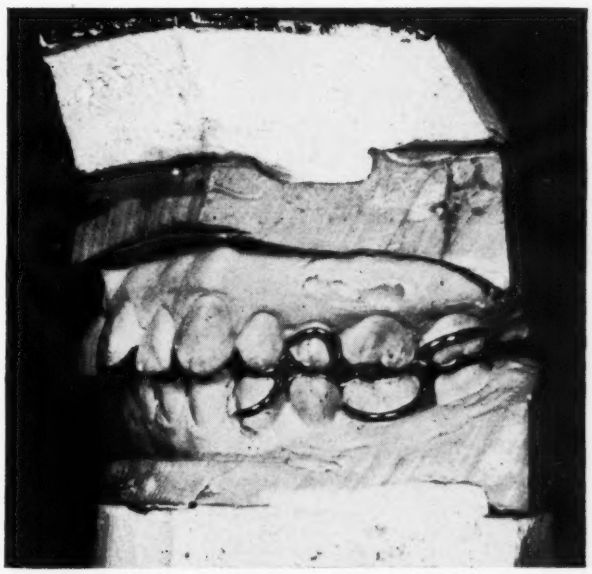

Fig. 8.—Occlusion provided by upper and lower metal removable occlusal guides.

A fourth is the construction of occlusal guide splints of acrylic or metal. These are generally indicated as a temporary treatment, and as a proof step of the proposed restorative dentistry. They are particularly helpful in case analysis, for the relief of tension, and for providing a proposed level of occlusion. It is possible, by this means, to return the patient to the existing occlusion, or to make changes without carrying out an involved procedure.

The fifth is the use of restorations by inlays, crowns, and fixed or removable bridges.

The sixth is the use of removable restorations which include occlusal pad guides to build up the natural teeth. This also provides for an immediate placement of the desired occlusion. With proper hygiene, the removable type of restoration will provide a good occlusal rehabilitation (Fig. 8).

The seventh is surgery which may be used in the more radical type of treatment. Caution is indicated, and a thorough diagnosis of the restorative treatment should be made before surgery is considered. The centric relation and vertical dimension to be established after surgery may be predetermined by the diagnosis of the relation of the casts on the articulator.

At the present time, there are several general techniques of determining the intermaxillary relation for occlusion. One is the use of the occlusion as it is presented as the intermaxillary relation. Possible changes are made from that relation. This may be considered an acquired centric relation. The second is to use the Gothic arch tracing to indicate centric relation. The third is to use the registration of rest position, which is a physiologic relation, as a means for determining the intermaxillary relation.

In a normal occlusion, when all the teeth are present in a normal relation to the muscles, and the condyles are in their normal relations, the apex of the Gothic arch and the rest position both place the jaw at the same position. When there has been a history of trauma, loss of teeth, and damaged occlusion, the resulting required compensating movements of the mandible may have caused some changes in the temporomandibular joint, as well as muscle tension which would affect the Gothic arch tracing. This was evident in my original work in gnathodynamics. While the patients were recording the maximum biting force with a central bearing point on a flat steel plate, they were free to move into a position of comfort because of the maximum effort required. These positions were recorded as "power points" on the steel plates. A Gothic arch tracing was also recorded at the same vertical dimension which provided a two-dimensional graph which indicated the horizontal relation of the jaws.

In over four hundred cases, 65 per cent of the patients recorded their maximum power in the area of the apex of the Gothic arch. In 35 per cent of the cases, the power points were from 1 to 7 mm. protrusive to and some lateral to the apex of the Gothic arch. The amount of power recorded was as much as twenty pounds greater in the relations which were out of the apex of the Gothic arch. This indicated the necessity of a balanced occlusion in relations other than that at the apex of the Gothic arch to provide a balanced occlusion in relation to the vertical force. The patients were originally treated by using the jaw relation indicated by the apex of the Gothic arch, and balancing the occlusion into the other relations. This required practically flat cusps, because a cusp tooth would have the biting force directed at an inclined plane, if it was arranged in occlusion with the jaw position not at the apex of the Gothic arch.

The patients were examined after weeks and months of use. It was found that the apex of the Gothic arch and the power point seemed to coincide, except in extremely retruded cases. At that time I thought that the power points were returning to the apex of the Gothic arch. However, in the last five years, many patients with teeth have been treated using the closure from rest position as centric relation. At the time of original treatment, Gothic arch tracings were made and the apex was noted to be in a retruded position from the rest position. In other words, the rest position was in protrusive as compared to the apex of the Gothic arch.

Almost all of these patients had indications of trauma, and many had a distal thrust. When a balanced centric occlusion was provided in closing from rest position, it was found that after a period of weeks some of the Gothic arches changed to the centric relation which was determined by closure from rest position. This would seem to indicate that there had been a change in the tissues and structures which affected the registration of the Gothic arch. For these reasons, and on account of the physiologic function involved, I believe the use of rest position provides an anatomically balanced centric position. The treatment of the patient may be varied for those who wish to use the Gothic arch as centric relation by first creating a balanced occlusion and conditioning the patient. Another method is to recognize the possibility of varied centric relation positions, and condition the patient.

Sufficient time should be provided for the tissues and structures to be returned to normal, and the tensions should be relieved. After a period of conditioning and treatment of the patient, the Gothic arch may be used as there will be a correlation between rest position and the apex of the Gothic arch. The two registrations may be recorded at any time in the treatment and, when they correlate, it is reasonble to assume that the centric registration may be accepted as the anatomic position of centric relation.

Over the past several years, many patients have been successfully treated who had various types of trauma, including many with facial pain and temporomandibular joint involvement. A diagnosis of the involvement of occlusion as a cause of temporomandibular disturbance may be made from rest position.

This study is offered as a contribution toward the solution of the problem of vertical dimension and centric relation. The suggested treatment may be utilized in restoring the occlusion to a physiologically normal relation.

SUMMARY

1. The basic diagnosis for occlusion requires the location of the vertical dimension, centric relation, and horizontal rotation center of the mandible.

2. Rest position and position of maximum biting force coincide in vertical dimension.

3. The occlusion, muscle function, and temporomandibular joint must function in harmony.

4. Temporomandibular pain may be the result of abnormal pressure on the connective tissue in the glenoid fossae.

5. The maximum vertical dimension is the dimension at rest position or maximum force, minus 2 mm.

6. Patients should be conditioned for jaw registrations.

7. Treatment planning may be done after mounting the casts on an articulator and establishing the proposed intermaxillary relation.

8. Rest position is in the range of a normal hinge axis movement of the mandible.

9. Rest position is selected as the diagnostic position. The Gothic arch tracing may record abnormal conditions. The Gothic arch and rest position may be correlated by conditioning the patient.

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DIAGNOSIS AND TREATMENT OF TEMPOROMANDIBULAR JOINT DISEASES

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IN THE treatment of temporomandibular lesions,* a complete knowledge of the mandibular articulation is important as a basis for (1) repositioning the mandible in prosthesis, (2) establishing a normal intermaxillary relationship in orthodontia, (3) establishing occlusal balance in operative restorations, and (4) the treatment of the joint and reflex symptoms associated with abnormalities of the mandibular articulation.

The etiology of temporomandibular lesions is malocclusion, tooth destruction, disequilibration of masticating stresses, and inflammatory processes of the teeth and jaws. These may occur alone or in combination with the others, and with or without toxic and infectious influences.

The joint symptoms are caused by abnormal pressure by the condyle, producing an unguided mandibular articulation and a loss of muscle tonicity. This condition is described by Brussell.[1]

The causes of the associated reflex symptoms of the ear, of impaired hearing, otalgia, tinnitus, and vertigo are the pathogenic factors in the joint abnormality. The inflammation caused by trauma and the loss of muscle tonicity is the cause of symptoms associated with the eustachian tubes. Vertigo and impaired hearing are caused by focal infection.

In all diagnostic procedures, a close association and consultation between the physician and dentist is essential. Costen[2] points out that there is a complex and varied group of syndromes, and that their diagnosis and treatment overlap the dental and medical field.

CASE HISTORY

Before any treatment is attempted, a complete case history should be obtained. This will provide for differential diagnosis and chart the course of treatment. There are many ailments confused with temporomandibular lesions. Some of

Read before the St. Louis Society of Dental Science, St. Louis, Mo., Dec. 17, 1951.

Appreciation is expressed for the aid given by The Mallinckrodt Institute of Radiology of Barnes Hospital, The Ear, Nose and Throat Clinic of Barnes Hospital, the Faculty of Washington University School of Dentistry, and diagrams by the courtesy of Thomas R. Moore, D.D.S., St. Louis.

Received for publication April 22, 1952.

*The treatment of temporomandibular lesions was started in Washington University School of Dentistry in 1936 by Bland N. Pippin, D.M.D.[3] His case history records and other data were lost at the time of his death in 1945. At the present time, the diagnosis and treatment used are fundamentally the same.

these are sinusitis, brain tumors, facial neuritis, eustachian tube diseases, dislocation of the joint, tetanus, Bell's palsy, organic disease due to irritation near the motor nucleus of the fifth nerve, sarcoma of the jaws, temporal arteritis, hysteria, dental tumors and cysts, impacted teeth, injuries to the periosteum of the jaws, stomatitis, pulpitis, and abscesses.

The information shown in Table I should be recorded in the case history.

TABLE I

Name—Age—Sex—Date
Address—Phone number
By whom referred
Chief complaint and general information

Subjective Symptoms:
- Type of pain
- Duration (constant—intermittent)
- Course (mapped out on one or both sides of the face and frontal area)
- Period of greatest intensity
- Relation to function (eating, speaking, etc.)
- What produces pain
- Additional pain information

Headaches:
- Temporal—frontal—parietal—occipital
- Degree (duration—frequency)
- Correlation between headaches and subjective pain

Glossodynia (constant—intermittent)
Vertigo
Tinnitus
Subluxation and Trismus

Impaired Hearing—audiographic report:
1. Beginning treatment
2. During treatment
3. End of treatment

Injuries—Accidents-Fractures-Allergies-Endocrine Disturbances
Type of Arthritis—Diabetes

Vitamin Deficiencies:
- Diet (breakfast-lunch-dinner)

Report of Otolaryngologist
Medical Report
Additional Reports (as orthodontist-psychiatrist)
Mental Attitude

Objective Symptoms:
- Teeth missing (when—why lost)

Present Oral Condition
Casts (before and after treatment)
Vitality Tests
Laminagraphic and Dental Roentgenograms
Intraoral Roentgenograms
Treatment Advised
Subsequent Treatment
Date of Visits and Treatment Results
Final Examination:
- Laminagrams-photographs-audiograms

Condition of Patient—Result of Treatment
Follow-up Examination

The classification of laminagrams are made with the mouth in a closed position as suggested by Pippin.[3] The normal position of the condyle is determined by a line drawn from the lower border of the orbit to the center of the auditory meatus. Normally the upper surface of the condyle will rest on this line.

These classifications are: (1) Unilateral malposition: right or left, normal right or left malposed. (2) Bilateral similar malposition: right or left similarly malposed. (3) Bilateral dissimilar malposition: right and left dissimilarly malposed.

The malpositions are found to be anterior, posterior, superior, inferior, lateral, and possible combinations of these.

TREATMENT

The corrective treatment of temporomandibular diseases falls in the field of dentistry, mainly in prosthesis and orthodontia.

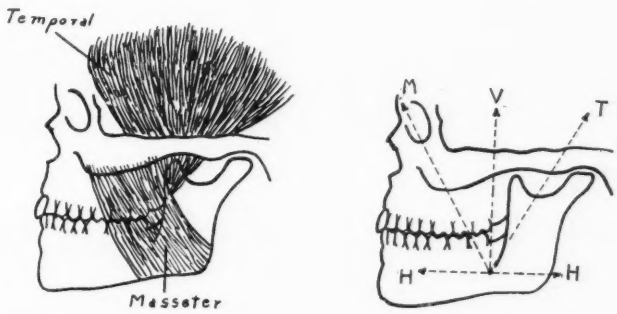


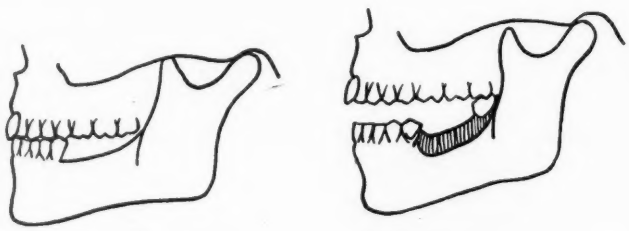
Fig. 1.—The position of the temporal and masseter muscles. *M*, Direction of the pull of the masseter muscle; *T*, direction of the pull of the temporal muscle; *V*, resultant; H, horizontal.

Physiotherapy, heat therapy, medication and sedation, bandages and splints are used to produce relief of the symptoms. It is important to maintain the proper jaw and muscular balance after treatment. The extraction of teeth for relief complicates the treatment. Many methods of increasing the interalveolar distance will increase the severity of pain and other symptoms. In all temporomandibular lesions, the proper repositioning of the condyle should be attempted before any surgical procedure is considered.

The splints used are metallic castings and acrylic occluding planes. The method of treatment will depend on the diagnosis of the case. If the pain is severe, elastic head bandages are used with the splints to hasten the movement of the condyle. The type of malposition of the condyle, as shown by laminagraphic interpretation, determines the construction of the splints. These splints are placed so as to act as a lever to correct the condylar malposition. They are placed on teeth posterior to the mesial surface of the lower first molar teeth, because the resultant force of the muscles of mastication is in the area mesial to apexes of the roots of the lower first molar. By placing the splints posterior

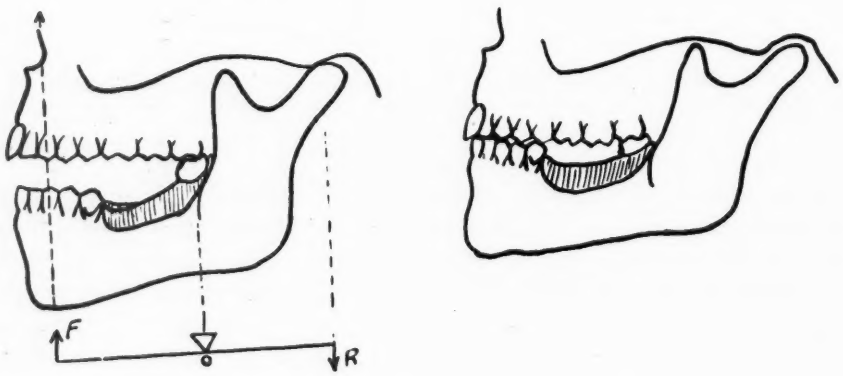
to area of the resultant force, the muscular pull will reposition the condyle without the use of head bandages and cause less soreness in the joint. The force of muscular pull and the position of corrective splints is shown in Figs. 1 to 3.

The condyle can be moved posteriorly by designing the splints so that the force is on the distal incline planes of the upper molar cusps. This type of splint is used in condylar malposition of the superior anterior type. For the superior posterior malpositions, the splint is designed to have the force come on the anterior incline planes of the upper molar cusps. The condyle can be moved laterally by designing the splint so that the force comes to the inner or to the outer cusps of the upper molar teeth.



A. *B.*

Fig. 2.—*A*, The superior anterior malposition of the condyle.
B, The position of the corrective splint.



A. *B.*

Fig. 3.—*A*, The direction of the muscular pull with the splints in place.
B, The corrected position of the condyle.

When the symptoms are relieved, it is important to check the vertical height. The permanent restorations are constructed to restore the correct vertical height, and the splints are removed. A new balanced occlusal plane is established. When there is absorption of the gums from dentures, there may be a return of former symptoms but they are never as severe. Usually this condition can be controlled by relining the denture and restoring the proper vertical height.

CASE HISTORIES

Two case histories are presented to give an insight for the treatment of temporomandibular lesions.

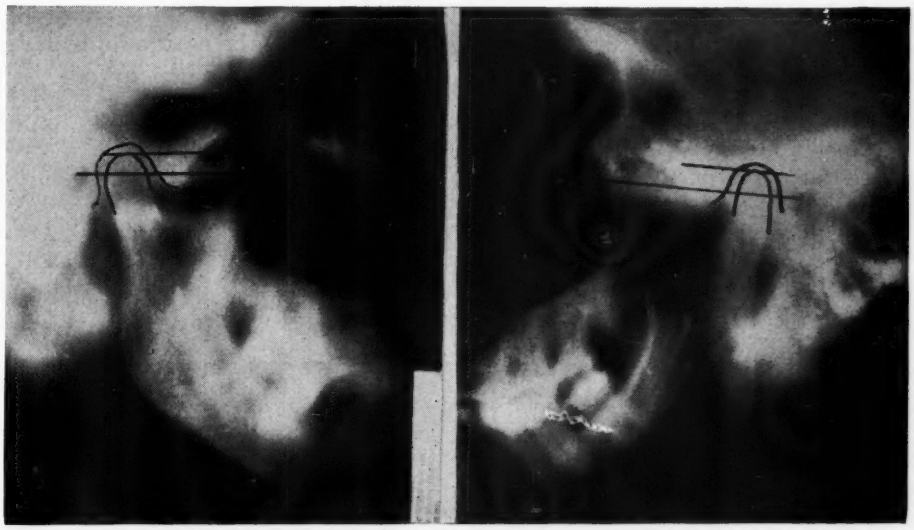


Fig. 4.—Laminagrams showing bilateral superior displacement of the condyles.

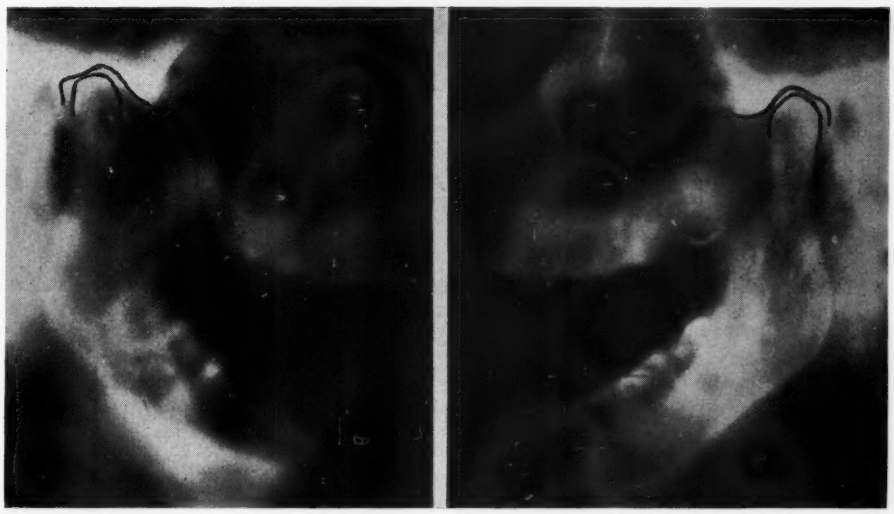


Fig. 5.—The condyles remained in the fossae and permitted only limited opening movement.

CASE 82.—A 51-year-old-woman, examined Oct. 6, 1949, was referred by the Ear, Nose and Throat Clinic of Barnes Hospital. The chief complaint was of an almost constant pain in the ears and head. There was a popping noise in the left ear. The pain started two and one-half years previously. The type of pain was a severe "shooting" pain in the ears and a "drawing" pain in back of the head. The course of the pain was on the right side, from the ear downward

along the mandible to the chin. There was a soreness in the temporomandibular area on both sides of the face. The patient had to force her mouth open to eat. A spoon would barely pass between her teeth. The pain was more severe when she was eating or talking. Headaches of a mild degree started a month previously. They were intermittent and of short duration, or at other times they lasted all day. Sometimes there was dizziness or vertigo. The hearing of both ears was impaired. There was an extreme nervousness but a good mental attitude. The Ear, Nose, and Throat Clinic gave a negative report. There was a history of eye trouble and a gallstone operation. The lower right first molar was missing, the occlusion was good, and there was a slight periodontal condition. The diet was poor because of the difficulty in eating.

The laminagrams showed a bilateral superior displacement (Fig 4). In the open mouth position both condyles remained in the fossae, showing limited movement (Fig. 5). The intraoral radiograms were normal.

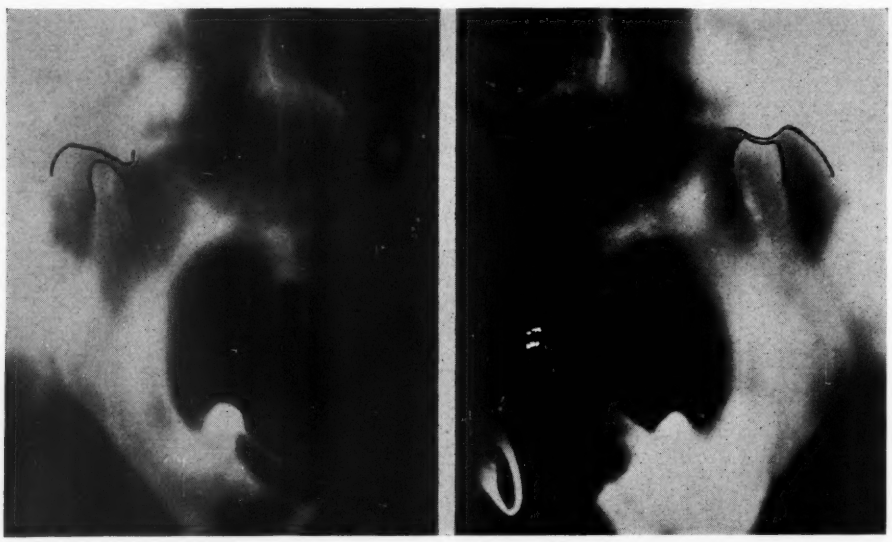


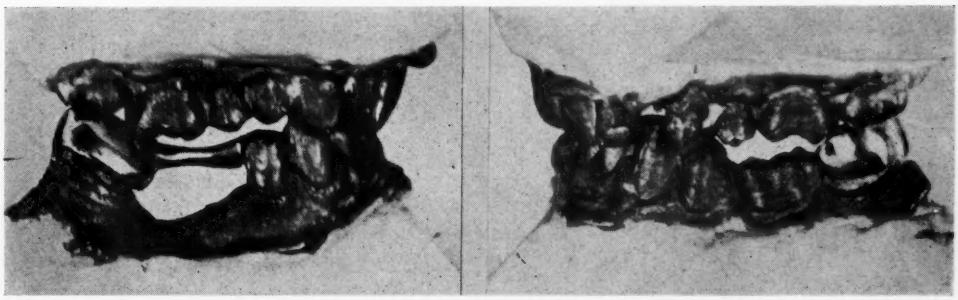
Fig. 6.—After treatment the condyles showed normal movement when the jaws were opened.

Treatment was started Jan. 5, 1950. Splints were placed bilaterally to provide for a 3 ml. correction. By May 11, 1950, all symptoms had been relieved. There was a normal opening of the jaws. No head bandages were used; the normal muscle pull was sufficient to reposition the condyles. Follow-up examination to Sept. 27, 1951, showed no return of the symptoms. Follow-up laminagrams with the mouth in open position showed that both condyles moved from the fossa (Fig. 6).

Case S4.—On Oct. 11, 1946, a 35-year-old man was seen. The chief complaint was pain "like a cramp" in the muscles of mastication on both sides of the face. There was a clicking noise in both temporomandibular joints. There was soreness in this area upon pressure. The pain was severe and intermittent lasting from one to thirty minutes. The course of the pain started in the ears

and radiated to all parts of the face. The period of greatest intensity was at mealtime or while talking. There was an impediment of speech. A breeze from a fan or movement of face muscles would produce pain. The patient had a blank expression. The pain started three years previously, and gradually became more intense and of longer duration. He had occasional headaches in the temporal area. They were not severe and lasted from a few minutes to two hours. There was a correlation between the pain in the muscles and the headaches. There was tinnitus in both ears. The report of the otolaryngologist was negative. The medical report was normal. The patient's mental attitude was good.

The upper left cuspid, lower right first and second bicuspid, lower right first molar, and lower left second bicuspid had been missing for fifteen years. The oral condition was bad. The diet was good. The lower jaw was underdeveloped. There was an extreme overbite, with the lower incisors striking the palate lingual to the upper central incisors.



A. *B.*

Fig. 7.—*A*, The splint used for treatment. *B*, The occlusion before treatment.

The laminagrams showed a bilateral superior anterior displacement of the condyles. Intraoral radiograms showed an abscess on the lower right central incisor and the pulp of the upper left first bicuspid was exposed.

Corrective splints were made to provide for a height of 2 mm. bilaterally (Fig. 7).

Treatment was started Jan. 20, 1947; by May 10, 1947, all symptoms were relieved. On Oct. 18, 1947, onlays and bridges were completed to maintain the vertical height and restore the occlusal plane. Casts were made before and after treatment (Figs. 8 and 9). The follow-up examinations showed no return of the symptoms during four years.

SUMMARY

Of 260 patients who were examined for treatment of temporomandibular joint lesions by repositioning the condyle, 140 were accepted for treatment, 75 were completed (Table II), and 65 have not been completed. The causes for uncompleted treatment were lack of funds, illness, moving to distant cities, psychopathic disturbances, or treatment still in progress.

Fig. 8.—Before treatment.

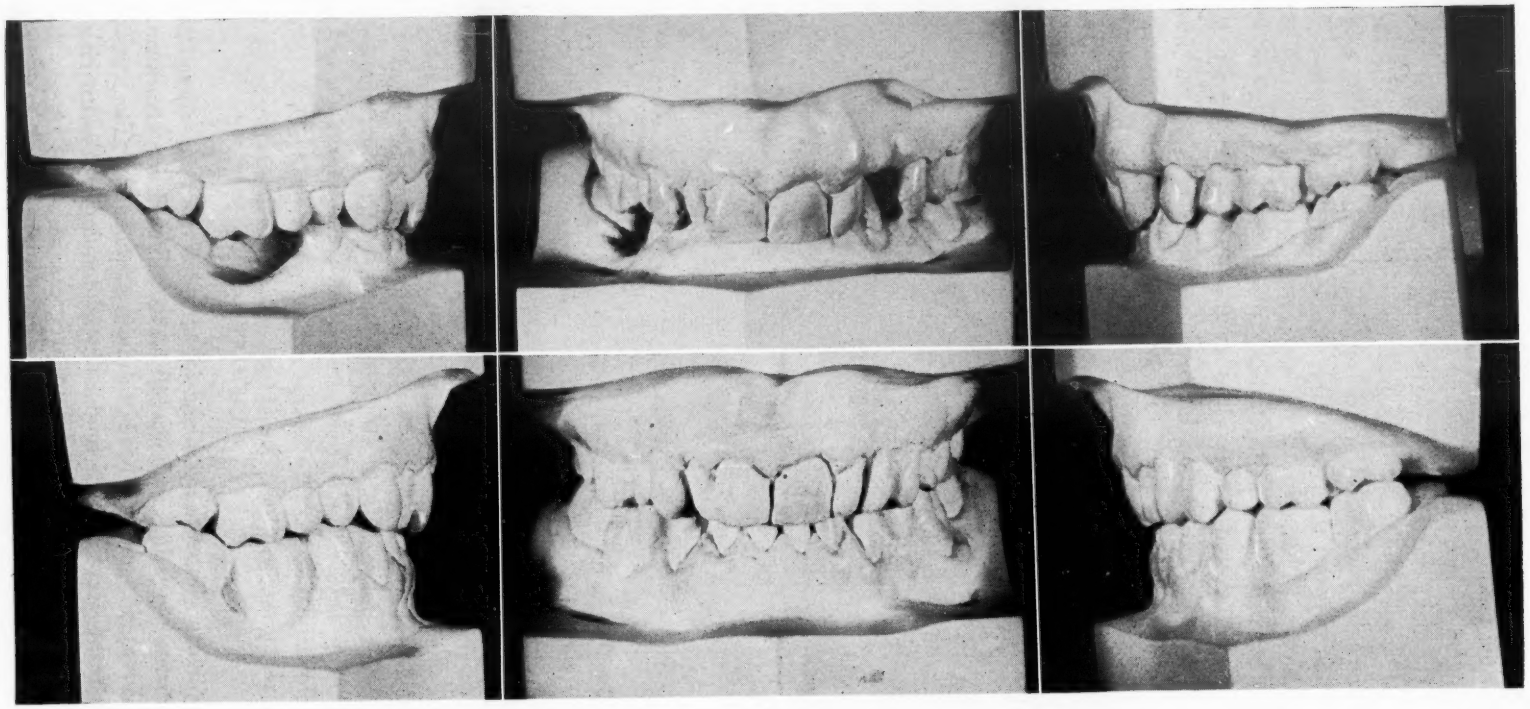


Fig. 9.—After treatment.

TABLE II. DATA ON 75 COMPLETED CASES

AGE (YEARS)	NUMBER OF PATIENTS	SEX (TOTALS)	ORAL HYGIENE		TEETH	
			CONDITION	NO.	CONDITION	NO.
10 to 20	1	Women 53	Good	40	Some missing	44
20 to 30	11	Men 22	Fair	20	Edentulous	23
30 to 40	15		Poor	15	Intact	8
40 to 50	18					
50 to 60	15					
60 to 70	11					
70 to 80	4					

SYMPTOMS	DURATION OF PAIN	DESCRIPTION OF PAIN
Pain; along branches of fifth nerve	Constant 26	Needlelike
Nervousness	Intermittent 49	Sharp
Soreness in joints		Darting
Subluxation		Dull ache
Popping noise in ears		Throbbing
Headaches		Shooting
Tinnitus		Steady pressure
Vertigo		Sudden
Impaired hearing		Like electric shock
Glossodynia		Twitching
Trismus		

COURSE OF PAIN		PERIOD OF GREATEST PAIN
Along the fifth nerve of different degree of intensity		Eating
Unilateral		Talking
Right	25	Change of weather
Left	32	Breezes
Bilateral	18	Lying down
Trigger areas	12	Swallowing

HEADACHES		EAR SYMPTOMS		TINNITUS		VERTIGO		IMPAIRED HEARING		GLOSSODYNIA	
NO.	%	NO.	%	NO.	%	NO.	%	NO.	%	NO.	%
39	52	36	48	36	48	23	29	20	26	10	13

TABLE II—CONT'D

LAMINAGRAPHIC INTERPRETATION	NUMBER
With mouth in closed position:	
Bilateral anterior superior	21
Unilateral anterior superior	8
Bilateral posterior superior	13
Unilateral posterior superior	1
Bilateral superior	12
Unilateral anterior inferior	1
With mouth in open position:	
Both condyles remaining in fossa	3
One condyle remaining in fossa	3
Left condyle slipping anterior to eminence	5
Right condyle slipping anterior to eminence	1
Normal	7

RESULTS OF TREATMENT

CONDITION	NO.	%
Good	66	88
Fair	5	6½
Poor	4	5½

In follow-up examinations, some cases show no return of former symptoms over a period of eight years.

CONCLUSIONS

1. Importance of proper diagnosis.
2. Repositioning of the mandible.
3. Maintaining of the proper vertical height and muscular balance.
4. Proper permanent restorations.
5. Sympathetic treatment of a highly nervous patient.

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PREPARING AND CONDITIONING THE PATIENT FOR INTERMAXILLARY RELATIONS

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THE PROSTHODONTIST is primarily concerned with restoring, and sometimes creating, efficiently functioning chewing mechanisms. At the same time he is concerned with restoring and maintaining the patient's oral and body health to the fullest extent of his ability, and giving the necessary attention to the esthetic side. Prosthetic techniques and procedures, through evolutionary processes, have been channeled into definite steps. So, while the whole operation is a continuous one, we visualize it as being divided into particular operations performed in a definite number of sittings which follow the same pattern of orderly procedure. Thus we discuss: (1) Examination, (2) planning, (3) patient preparation, (4) mouth preparation, (5) impressions, (6) jaw relations, (7) tooth selection and arrangements, (8) try-ins, (9) delivery or insertion of prosthetic appliances, (10) patient instruction, and (11) adjustment and corrective procedures. Experience has taught us that the more thought and care used in the first ten of these operations the less time will be required in the eleventh. The first ten steps may be accomplished in three, four, or five visits according to the difficulties encountered, the operator, or the technique. The eleventh step is dependent on the degree of efficiency to which the first ten steps have been carried out, as modified by the physical and mental condition of the patient.

Any one of the eleven steps or phases of prosthetic restorations is a subject for lengthy study and discussion. In this paper I shall try to bring the third, sixth, and eleventh steps (patient preparation, jaw relations, and adjustment and corrective procedures) into our thinking at one time, and to show their close relationship to and influence on each other. At the October, 1951, session of the American Denture Society, Kingery presented a most intelligent and comprehensive essay, "Problems Associated with Centric Occlusion."[1] Kingery divided his study into four parts: (1) the problem of what is required, (2) the problem of errors, (3) the problem of how errors manifest themselves, or as he heads this section, "Problem of recognizing the symptoms of errors associated with centric relation," and (4) the problem of recording centric relation. His paper applies primarily to the completely edentulous patient so, as far as possible, I will try to avoid repetition and discuss problems dealing with all other situations. These range from the immediate replacement upper and lower denture to any simple prosthetic dental replacement.

Read before the Academy of Denture Prosthetics, New Orleans, La., March 18, 1952.
Received for publication March 19, 1952.

In my experience in the field of prosthetics, as a practitioner, essayist, and clinician, and also serving as a prosthetic officer in the Army in charge of a large prosthetic laboratory, I have observed one defect which was apparent in a tragically large percentage of dental restorations. That defect is the frequent failure of dentists either to recognize errors in centric relation or to know what to do about them if they do recognize them. I feel that too much time cannot be given to this subject, and that too much attention cannot be focused on methods of teaching the subject to the dental student, both graduate and undergraduate.

We must clarify to the dental profession that recording centric relation is not a simple direct procedure that we can close the book upon as soon as we believe it is obtained. A survey of present-day practices will show that too many casts sent to commercial dental laboratories for partial denture restorations are articulated by touch, or by interdigitation of worn facets on the teeth which guide the casts to eccentric positions, thus perpetuating deformities in jaw relations. Very few immediate denture replacement patients receive the necessary treatment of being restored to proper centric relation before the dentures are started. Very few complete denture patients are given the consideration, or admission by the dentist, that his records may be wrong at the mounting stage. Far too many occlusion rims for complete dentures are loose and ill fitting and, in this unstable state, slip and slide off their bases. Most edentulous patients who are wearing old ill-fitting dentures and presenting for new dentures have two characteristic barriers to success. Those dentists who spend many hours studying, teaching, and constructing dentures are on the alert for them, but not so the average dentists. Those barriers to success are: (1) tender areas which make it inadvisable for impressions to be made until they are healed, or make it uncomfortable for the patient to close the jaw properly, or without some mandibular shifting, and (2) uneven muscular tension which is acquired through years of absorbing anatomic bases, abrasion of teeth, tenderness, psychologic factors governing muscles, chewing habits, etc.

This is not a situation unknown to you. It is an old story, but one which necessarily concerns us all. With the increasing life span among our citizenry, more people are reaching the denture-wearing age every year. Dental health education of the public is bringing many more patients to all dental offices, and the importance of replacing missing teeth is finding increasing acceptance in the public mind. Population increases and patient load increases seem to be progressing more rapidly than the available dental service. It would seem incumbent upon us to see that good prosthetic service be rendered to the greatest number possible in the fewest possible visits. This can *not* be done by compulsory health insurance, but it *can* be done by self-analysis of our teaching, and by trying to find simpler, more crystal-clear methods of conveying our learning and experience to the student. We can teach the student to memorize the definition of centric relation. We can demonstrate arrow-point tracings and soft wax check bites. These sound fundamentals are necessary for formal learning. However, I believe we should also teach both the dental student and the patient that proper centric relation is a state or a condition of a part of the body, and that if this condition is lost, or improperly restored, it makes the restoration of health and comfort very unlikely.

The physician, when treating an illness, prescribes a drug which may produce a cure immediately. This situation may be compared to the denture patient who places his jaw in the correct centric relation quickly and with no difficulty. But if the first drug does not help the patient, the physician is not considered a failure. He changes or adds to the prescription. The doctor, if he is diligent and fortunate, with his training, skill, and patience, and the patient, with confidence and understanding, combine their efforts and effect a cure. A number of visits may be necessary. Likewise the dentist and the patient should know that time and skill and patience are necessary to produce a satisfactory cure, or restoration of occlusal health. With this acceptance and understanding on the part of dentist and patient, the dentist will be less hesitant and embarrassed at making rechecks, testing, and looking for errors. This philosophy or attitude is far more likely to bring about cooperation between the operator and the patient, with both seeking and working together. This attitude must be contagious and must also affect the auxiliary help so the assistant does not rush the dentist and so the laboratory technician understands the value of remounting casts, maybe several times.

Let us teach the dentist the value and importance of preparing the patient for this prosthetic dental operation. Our goal in "patient preparation" is to establish the maximum confidence and understanding on the part of the patient. This is not always possible, but the closer we approach the goal the better our chance for success. I have always believed that the old masters of prosthetic dentistry, the "name men," can attribute many successful results to the fact that they radiate confidence, and their patients, becoming exposed and infected with that confidence, are relaxed with the assurance that their dentures will be a success. A relaxed patient is practically a requisite for success, and the beginner does not yet possess the reputation or the confidence to radiate upon the patient. I believe some of you great teachers should spend as much time in teaching patient preparation as you spend in teaching the mechanics of examination and technique.

Patient preparation should actually be under way when the clinical oral examination is being made. There is a great advantage in handing the patient a hand mirror, and asking him or her to follow the dentist during the examination. Good illumination being available, the patient becomes interested and education begins at once. Conditions of the mucosa, hard areas, flabby areas, bearing areas, inflammation, the normal and the abnormal are all pointed out to the patient who, if properly prepared, becomes an associate operator. If the patient has any teeth, either natural or artificial, there is a great advantage in studying the opening and closing movements while the patient is watching in the mirror. It is explained that some of the movement is up and down as on a hinge, and that our problem is to see that the hinge is in the right place. The patient should be told that the mouth must be free of tender areas, the jaws free of pain to pressure or movement, and the muscles of the jaw, the face and, in fact, the whole body should be relaxed. The patient should understand that some people are more tense than others and that being tense under strenuous conditions is perfectly normal. He should under-

stand that the term "strenuous conditions" can apply to both physical and mental pressures that are present, in varying degrees, most of the time. It can usually be demonstrated, with some guidance of the mandible by the dentist, what is meant by premature occlusal contacts, and how these early contacts cause a shifting of the mandible at the completion of the closing movement. If the patient is uncomfortable or extremely tense, this fact can be brought out, and the need for establishing a more relaxed state is easy to demonstrate.

With the patient now versed in the fundamentals, and knowing generally what is to be done, his fears and apprehension are replaced with a cooperative and interested attitude. The patient is not stimulated into an overoptimistic state, but is educated, and has sound facts upon which to base his expectations. The time spent on patient preparation will reduce the time to be spent on "jaw relations" and "adjustment and corrective procedures" enough to more than justify itself.

By the time we come to jaw relations, we should have a patient who is thoroughly competent to manage his or her role in the procedure. In previous papers,[2] I have discussed the "RR" or relaxing routine which is carried out in practically every case in my office. For years I have put my patients on a soft diet, mild sedation with barbiturates, and had them apply hot wet packs to the jaws three times daily for two to three days prior to recording jaw relations. This of course is to produce a relaxed state, free from muscular tensions which are abnormal and beyond the state of tonicity which maintains normal posture. Then, to quote Jacobson,[3] "With progressive muscular relaxation, thought process and emotion gradually diminish."

In extreme cases, the relaxing routine mentioned may not be sufficient. During the past year I have had two patients, both with temporomandibular joint disturbances, in whom results were unsatisfactory until 50 mg. of Demerol Hydrochloride and 10 grains of aspirin were added to the customary rest, heat, and sedation. One of these cases was characterized by extreme pain in which there was marked erosion of the condyle head, as was evidenced by roentgenogram. This man was unable to open his mouth beyond a hinge movement of a few millimeters without paroxysms of pain. The additional sedation relieved the pain, allowed relaxation, and permitted a jaw relation record which was vastly different than any ever previously recorded. Prosthetic appliances built to this new centric relation restored comfort and nearly 100 per cent relief within thirty days.

The second patient needing the extra dosage of sedation was a middle-aged woman, wearing a complete upper denture against natural lower teeth. She was the wife of a dentist. Her history was one of having several upper partial dentures, each replacing a tooth or two more than the preceding one, and apparently every one perpetuating the deformity caused by a shifting of the mandible to the right. This had resulted from a lower left second molar which was tilted forward. It had a high distal cusp which in all probability contacted the upper occlusion rim, and then guided the mandible to the right. Years of shifting to the right had produced a trismus in the muscles of mastication, which required the additional sedation to reduce. In addition to the Demerol and aspirin, this patient was treated by a physiotherapist with rapid sinusoidal current. This current

is entirely mechanical in its action, and possesses neither polarity nor chemical effects. It can be used for preliminary anodyne treatment of acutely sensitive sprains, myositis, and neuralgia.

Chewing or exercise with the degenerative joint aggravated the inflammatory condition and its accompanying trismus, but the fine vibratory massage of the rapid sinusoidal current seemed to aid in relaxing the musculature. In taking the history of the patient just described, I learned that at least six dentists had constructed restorations, from the first partial denture to the complete denture she was wearing when I first saw her. All of these men missed the two points which should have been apparent. These were the uneven occlusal plane with a high molar tilted forward and the trismus. This patient was doing satisfactorily at the last report. The method used to obtain relaxation is not important, but the need for relaxation should be taught and demonstrated and stressed to the student.

Boos[4] recommends what he terms "prescription exercises" for the patient prior to recording jaw relations. In my experience, these exercises are excellent in routine dental reconstruction or denture cases. My patients who were under treatment for pain in the temporomandibular joint tried these exercises. Some were unable to complete the cycle or to cooperate fully because of the pain on stretching. More should be learned about the value of exercise as we have more experience.

The two extreme cases were described in order to emphasize the value of relaxation. The average pain-free patient may require just as much care, attention, and "patient preparation." The goal is the same in either instance.

When the relaxed patient gives the proper jaw relations and they are recorded, the adjustments and corrective measures will be reduced to a minimum. The dentures, if correctly mounted for the try-in, will still be correctly mounted for the correction of the processing errors. Other adjustments will then be restricted to modification of the denture borders or other minor changes.

There is a wonderful opportunity for a study club or an institution with the ingenuity, initiative, facilities, and the funds, to construct large working models which will make the subject of jaw relations easier to study and easier to learn. I feel there is a great need for this in our profession. Maybe this plea will be the challenge to one of you which will result in a real contribution entitled "A Primer of Jaw Relations and Occlusion."

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MUSCULAR TENSIONS AND PROSTHETIC DENTISTRY

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IT IS highly significant that specialists in denture prosthetics have concerned themselves with muscular tensions. While most dental patients can safely be regarded as requiring simple routine services and accepting them casually, some deviate so far from patterns of mental normality that they must be considered as psychophysical wholes if prosthetic dentures (or dentists, for that matter) are to be much other than foci of irritation and anxiety to them.

It is with these deviates that we are presently concerned. They are a very small percentage of the generality. Clinicians often exaggerate their incidence because of the individual attention they require or receive. Most individuals adjust well to and correct excessive muscular tensions incident to usual and unusual elements in their environments. (Most people are remarkably adaptable.) Much attention to muscular tension states of most individuals is not only unnecessary but undesirable.

A re-examination of the fundamentals of muscle tension and muscle tension states is recommended. These have too often been neglected, not only by clinicians but by experimentalists in physiology, psychology, neurology, psychiatry, and other related fields as well. As a result, our present understanding of muscle tension in normality, in psychopathology, in organicity, and as a manifestation of personality is regretfully limited. We have built sketchily upon the basic work of such investigators as Pavlov,[44] Cannon,[5] Jacobson,[20,21] and others.

Perhaps psychology can render some aid to dentistry regarding muscular tensions, particularly as to what constitutes normality and abnormality. You have had more concern with the mechanics of the human organism than have most clinicians. Many of you are more sophisticated in these areas than am I, or than are most psychologists.

Despite your training and experience in this area, I suggest a review, at least mentally, of the nature of muscular contraction, [17,40,42,49,53] of the "all-or-none" principle of muscle response,[49] of the role of the central nervous system in muscle tension,[17] and of the characteristics of the startle response.[6, 21]

Read before the Academy of Denture Prosthetics, New Orleans, La., March 18, 1952.

The opinions and conclusions contained in this paper are those of the author. They are not to be construed as necessarily reflecting the views or the endorsement of the Air Force.

Received for publication June 2, 1952.

MEASURING MUSCLE TENSION

The problems of measuring muscle tension are legion and have bedeviled psychologists and physiologists for at least two generations. The clinician often infers muscle tension from superficial behavior patterns and from complaints and organicity which he has come to associate with muscle tension states. The researches of Johnson,[23] Duffy,[10,11] Jacobson,[20,21] Landis and Hunt,[30] Davis,[6-8] and others show that this is hazardous since many muscle tensions (perhaps the most serious ones) are imperceptible. It is not infrequent that a patient appears to be tense, says he is "all tied up in knots," and yet, by laboratory measurements, tensions are well within normal limits. On the other hand, many patients give no outward or symptomatic evidence of excessive tension, yet laboratory measurements indicate extreme tension.

Diagnosis of muscle tension by clinical observation is further complicated by what Landis and Hunt[30] call "secondary behavior" or "personal and social habits." In the clinical situation these frequently mask muscle tensions. Actually, much of the muscle tension takes place too rapidly for observation and generally is dissipated within a few hundredths of a second.

Muscle tension has been measured in the laboratory by a wide variety of methods. Today electronic devices are most commonly used. Generally electrodes are placed in the muscle or subcutaneous in external relation to it, as in the researches of Jacobson,[20,21] or on the skin external to the muscle, as in the researches of Davis.[6-8] Electric potentials and changes in these potentials are measured and recorded. Jacobson,[20] by about 1930, measured potential to the nearest one-millionth of a volt. Change in potential with muscle tensing is very rapid, most of the change in the startle response, for instance, taking place in the first one-fifth second following administration of the stimulus. The electric accumulator as developed by Jacobson[20] accumulates changes in potential for successive units of time. Accumulations for successive tenths of a second have been used in many studies. In experimental situations measurements of electropotential are synchronized with changes in the psychologic or physiologic environment. A stimulus may be a sudden, loud noise, as in the researches of Landis and Hunt[30] and Davis,[6] or experimental stress-producing situations as employed by Malmo and associates[40] in their study of normal and psychiatric patients, or different types of mental activity as in the researches of Duffy.[10]

We have become accustomed to the electronic measuring devices used in physiology, psychology, neurology, and criminology under a variety of names—the mylograph, the electroencephalograph, the electrocardiograph, the lie detector, and so forth. They all measure electropotential in electroactive tissue. It is generally assumed that these measurements are manifestations of the activity of the tissue under investigation, even though direct contact with the tissue is not established. From these measurements conclusions are drawn concerning the total organism or some part of it. Whatever error may be inherent in this hypothesis, the accumulated data indicate that the potentials measured by the mylograph do evidence muscle tension.[33,51] That abrupt change in electropotential of the muscle may be indicative of abrupt change in emotional state is well established. That

high muscular tension (electropotential) invariably manifests emotional imbalance does not follow.

Using measuring and recording devices of this type, Davis[7] demonstrated muscle tension responses to auditory stimuli so faint that they were not reported as heard. These were measurable during periods of from 0.2 to 1.8 seconds after stimulus onset. Responses to unheard stimuli were smaller than to those reported as heard. The auditory sensitivity of individuals was found to be related to their prestimulus muscle tension levels. Muscle tension levels differed from different geographic locations of the body investigated, were present in all, and were most pronounced in measurements from the right masseter muscle.

It appears, then, that dentists do their work on or proximal to the most violently responsive muscles of the body. Furthermore, the extreme tension of these muscles may provide partial explanation for the etiology of neurosis in those so predisposed (readily susceptible) who require or receive much dental attention, particularly if their susceptibility is not understood by their dentists. With these patients, there would seem to be ample justification for heavy sedation or hypnosis as a neurosis-preventive measure. How much time should elapse between dental appointments to avoid reinforcement of high muscular tension response, and the amount of dental work that should be done at one visit are questions to which there are no readily available answers.

The exact nature of the relationship between electropotential of the muscle and muscle operation is largely unexplored. What actually takes place in the muscle that is associated with electropotential? What are the psychologic correlates of these measurements? How are the muscle tensions and correlated electropotentials initiated? How are excessive muscle tensions maintained? How exaggerated, as in some pathologies? How shall we account for the great individual differences in muscle tension and in tolerance for it, and for the wide range of variation within an individual? How can excessive muscle tension be reduced to normal level quickly and safely? How much damage is done to body structure (as in the temporomandibular syndrome)? How much malfunctioning results from muscle tension and when and how does this induce organic pathology? To what extent is somatization a result of muscle tension and vice versa? How can we reconcile the contention that somatization is an escape reaction or solution-seeking device with what we know about muscle tensions in the pathologies and near-pathologies? What are the consequences of exaggerated loss of muscle tension characterizing flaccidity and dysfunction? Orthopedists are well aware of the problem of hypomuscular tension, guard against, and strive to correct it. Pain incident to relaxation (decreased muscle tension) is commonplace with orthopedic injury. (I have recently experienced this with a bone splinter in the capsule of the right shoulder joint. With relaxation pain was severe; with normal working activity tension it was mild to absent.) Is it possible that, in the temporomandibular syndrome, decrease of muscle tension exerts pressure on damaged tissue with resultant pain? If so, this would account, in part at least, for the near-reflex-tension response reported as a part of the syndrome.

These are some of the questions which the clinicians in all specialties must try to answer. We cannot presently answer all of them, nor perhaps any of them fully. However, some investigations provide points of departure from which we may go to more searching studies, additional scrutiny of our hypotheses, and to more effective clinical practice.

STARTLE RESPONSE

The startle response provides an illuminating source of information relative to muscular tensions. It is seemingly a response involving the whole organism. It is general to all normal human beings. It is unlearned. It can be conditioned and the conditioned response suffers extinction through disuse, as do all other learned responses. Many characteristics of the response are so gross as to be readily observable, yet much of it is revealed only by the high-speed camera and electronic amplifier.[30]

DISSIPATION OF MUSCLE TENSION, NORMALITY, AND PSYCHOPATHOLOGY

Muscle tensions arising in one part of the normal body tend to dissipate peripherally, that is, scatter throughout the entire musculature. Conceivably, pathology may result from failure of such dissipation. Cameron and Magaret[4] go so far as to define *anxiety* as the ". . . predominantly covert skeletal and visceral reaction which constitutes the unconsummated, preliminary phase of emotional excitement." It is not unlikely that much of the efficacy accredited to certain psychotherapies results from dissipation of muscle tension. In talking of and reliving stress-related experiences the patient frequently dissipates muscle tensions, thereby affecting therapy. It seems more likely that resolution of conflict comes from responding differently (without excessive or undissipated muscular tension) to ideation conflict or stress than from insight or understanding. The researches of Rogers[40,47] on nondirective therapy tend to support this conclusion.

NORMAL MUSCULAR TENSIONS

In normality, muscle tension makes up much of the warp and woof of living.[21] It is of central nervous origin and is coordinated in such a manner as to serve the welfare of the organism as a whole. Only such of the motor areas are excited to function as are necessary for evoking the particular reaction that is appropriate.[17] It is not an exclusively nervous function, yet the nervous system is the chief integrating apparatus. In normal man, the control of behavior by the brain is greater than in any animal and, presumably, coordination by the central nervous system is a correlate of evolutionary stage.

Muscle tension is residual in the normal human being, even in the sleeping stage, to a degree compatible with physiologic need and to sense of need for alertness, for instance, as in a combat zone; also, for conformity to social customs, and so forth. (In our culture, it is deemed "normal" to maintain tensions on the sphincter muscle of the bladder sufficient to delay micturition.)

Residual muscle tension varies tremendously from individual to individual. As described by Duffy,[10] it is energy mobilization and one of the most significant aspects of personality. Muscle tension which is residually normal to one individual may be abnormal to another. Mylographically measured, the normal residual muscle tension of one individual, from birth, or nearly so, may be several times that of another individual equally normal. Human beings differ as radically as animals (dogs, for instance) in excitatory neural activity and associated muscle tension, and with equal normality. Correlatively, it is reasonable to assume that human organisms differ as widely in capacity to endure muscle tensions. But we do not know whether those geneticized with the greatest muscle tension are constitutionally best equipped to endure tension. It is doubtful that such is the case, though some individuals have astounding endurance or tolerance, physiologically as well as psychologically, for extreme muscle tension as well as for other and often associated atypical states. It appears that, in normal persons, dysfunction, impairment, or even destruction of the organism in association with high muscle tension is one of Nature's many idiosyncrasies.

Muscle tension is at a residual minimum during extreme relaxation, as in the normal sleeping stage. Apparently both excitatory neural stimuli and muscle excitability are reduced. How much of this reduction is of neural and how much of muscular origin seems uncertain. Electropotential of the skeletal muscles is lowered, yet tension is sufficient to maintain circulation of the blood and body fluids, (Johnson, Swan, and Weigard[25] found a major body movement about every seven minutes in normal adults in the sleeping stage.) Tension in the involuntary muscles decreases also and the vegetative processes proceed at a maintenance-plus-recuperative level. In sleep the muscle tensions decrease rapidly during the first forty to sixty minutes to a minimum which is maintained for three or four hours. Then, muscle tensions begin to increase, and rise to a magnitude that precludes deep sleep beyond physiologic need.

In normal individuals, muscle tension generally is so low that they are not well prepared for emergencies of which they have no forewarning. However, when an emergency is perceived muscle tensions mount rapidly and, even after muscle fatigue is extreme, ready energy (muscle tension) is attained by the action of adrenin. Cannon[5] described this as follows: ". . . adrenin has . . . a very remarkable action of restoring to a muscle its original ability to respond to stimulation, after that original ability has been largely lost by continued activity through a long period. What rest will do only after an hour or more, adrenin will do in five minutes or less." (Exhaustion of adrenin reserve through constant emotional imbalance may account in part for the lowered energy reserves of some abnormals, particularly the neurasthenics.) Muscle tension is seldom if ever maintained to a degree or for a duration sufficient for muscle exhaustion. Central nervous exhaustion sets in before muscle exhaustion, otherwise death would result.[50,51]

Muscular tension is readily established as a conditioned response. Tension responses to a loud noise or pain, for instance, can be conditioned to other temporally associated stimuli—another noise, an odor, and so forth. These appear, though not as strong, in the absence of the primary stimulus when the secondary

(conditioning) stimulus is presented. Significantly, in normality the conditioned muscle tension response suffers rapid extinction if not reconditioned. Were this not so we would all be victims of all the secondary stimuli occurring simultaneously, or nearly so, to those stimuli normally resulting in extremes of muscle tension. The soldier, fresh back from combat, who "hits the dirt" when an automobile backfires or the shadow of a bird flying overhead is cast across his path exhibits this type of conditioning. Normally this soon disappears from his muscle tension repetoire in a noncombat zone.

MUSCULAR TENSIONS IN PSYCHONEUROSIS

Duffy[11] early showed great individual differences of muscle tension in children, and tension was related to neurotic behavior such as stammering, enuresis, tantrums, restlessness, and avoidance of physical contact in play. Habitual, residual tension was not related to muscular strength.

Travis and Kennedy[55] found a direct relationship between muscle tension and speed of reaction.

These and other researches indicate that neurotic individuals have more than average muscle tension and react more rapidly to external stimuli. This seems in disagreement with the popular conception of muscular dysfunction in neurosis.

Jacobson[21] early described the psychoneurotic individual as unable to relax without instruction: ". . . the neurotic individual has partly lost the natural habit or ability to relax. Usually he does not know what muscles are tense, cannot judge accurately whether he is relaxed, does not clearly realize that he should relax and does not know how." He found in neurotic persons, when lying in a relaxed position, respiration slightly irregular in time and force, pulse rate moderately increased as compared with later tests, voluntary or local reflex activity revealed by wrinkling of the forehead, frowning, moving the eyeballs, tenseness in the muscles about the eyes, frequent and rapid winking, restless shifting of the head, a limb, or a finger, a reflex start to any unexpected noise, and so forth.

In terms of muscle tensions, we might describe the neurotic individual as unevolved. Paraphrasing Herrick,[17] his central nervous system does not coordinate his muscle tensions in such a manner as to serve the welfare of the organism as a whole. (Seemingly some will destroy rather than rest their jaws.) More of his motor areas are involved than are necessary for evoking the reactions that are appropriate to the total situation. In the words of Finch,[13] he is "stimulus bound." He responds to a multiplicity of stimuli to which the normal person is unresponsive, and he continues to respond with greater vigor to repetitions of the same stimuli. He is constantly mobilized for defensive action or flight. Excess secretion of adrenin keeps him so mobilized and renders him immune to muscle exhaustion such as the normal person would experience from comparable heightened and continuous muscle tension. His reflexes are sharpened and he is abnormally alert. Deceased viscosity of muscle tissue probably accounts for his increased speed of reaction. Generally there is no loss in muscle tonus resulting from this continuously heightened muscle tension, as many of you must have verified at

the expense of abraised and bitten fingers. In some way he avoids muscle exhaustion, as well as the brain fatigue described by Schwab[50] and Stevens and Davis.[52] Those who question these conclusions should try maintaining the same incessant movements, habitual tensions, and off-balance postures common to many abnormal persons.

The excessive muscle tensions of the psychoneurotic person, particularly, are manifestations of a fear or excitement response. The neurotic individual is chronically fearful or excited, and the more intelligent, the more he can be afraid of or over which he can be excited. He may lose awareness of or suppress the ideational correlates of his response, yet maintain the physiologic components, for example, improper mandibular posture. Harrington[16] explains emotion as either (a) a combination of muscle tensions, or (b) a blend of feelings to which these tensions give rise. Accordingly, in his thinking, emotional control is muscular control which may be achieved by posture which provokes proper muscular activity, and mental abnormalities result from failure to relieve muscle tensions, or improper relief of tensions. Whether this is literally the case, it does seem that strong emotion cannot be experienced without heightened muscle tension (which naturally has its effect on mandibular posture and centric relation). There is considerable evidence supporting the thesis that all imagery of movement, space, and so forth, is dependent upon tension of the muscles involved in direct experience of those phenomena.

MUSCULAR TENSIONS AND SOMA

We may well ask what relation muscle tensions bear to prosthetic dentistry. The same question might legitimately be asked for all medical specialties. The interaction of psyche and soma, in health and in disease, is well established. Block[2] and Block and Harris[3] have related the temporomandibular syndrome to muscle tension. Le Vay[32] has called attention to psychologic factors as causes of gross orthopedic disease. He concludes that emotion may greatly modify muscular tension, posture, and even osseous structure, and that the end results may completely obscure the prime causes.

We may postulate that where muscle tension causes orthopedic disease, it does so by applying stress to the body structure. Impeded circulation resulting from excessive muscle tension and chemical-electrical imbalances decrease the ruggedness of the body structure and its recuperative power. Thus, excessive tension applies stress beyond the tolerance of the physical structure, resulting in dysfunction or/and actual physical injury. It is reported that some individuals break their teeth in their sleep. This would illustrate the tremendous pressure applied by nonadaptive muscle tension. There seems ample evidence for acceptance of the conclusion of Block and Harris[3] that overextension of the external pterygoid muscle may result in a bending of the neck of the condyle, loosening and perhaps loss of teeth, or protrusion of the mandible.

One need not be a dentist to appreciate the simple mechanics involved. However, the psychologist might question that this condition often occurs in normal personalities without extreme structural defect or some other purely mechanical

difficulty. After all, one uses his teeth very little, and none too vigorously in biting and chewing in the world with which we deal. Normal individuals, not biting or chewing and not under stress, seldom occlude the teeth with much force, even when swallowing. They are usually slightly apart and seldom touch, as are the lips. Muscle tensions in the face and jaws are minimal, residual, or nearly so.

The muscle tensions of the normal person are centrally controlled relative to specific situations. If tension in the muscles of immediate concern to dentistry is excessive (markedly above that called for by the situation) we may conclude that, (a) we are dealing with a normal individual under stress who has not yet reacted to the situation with release of muscle tensions, or (b) the individual is abnormal in terms of muscle tensions, and (c) may or may not have an abnormal personality.

The normal individual reacts to pain with muscle tension. He relieves the pain, if possible, or to the degree possible, by release of muscle tension, through relaxation, or through mental or physical activity which may serve as a distraction, decreasing his awareness of pain, or dissipating muscle tension with resulting decrease in sensitivity to pain. If he attains even partial unawareness of the pain, muscle tension is decreased. The normal individual is very adept at adjustment. He seldom, under what we call normal living conditions, prolongs muscle tension to chronic physiologic dysfunction, orthopedic disease, or mechanical destruction of tissue. With malocclusion he will generally decrease or avoid biting and chewing. He will chew with caution and eat foods that do not need much chewing. If so predisposed, he may become neurotic through failure to modify his reactions and his diets to demands of malocclusion. It is not inconceivable that the normal individual under extreme stress, for example, where hunger is paramount and where diet cannot be modified, may become neurotic because of malocclusion.

The neurotic person is incapable of such adjustments. His reactions are not adequately controlled by the central nervous system. His attempts at adjustment frequently increase rather than solve his difficulties. He seeks release from fear through increased fear response, largely muscle tension. He responds to pain from malocclusion, faulty orthopedic structure, infections, and so forth, with degrees of muscle tension which aggravate these conditions, retard recovery, and often damage body tissue.

MUSCULAR TENSIONS IN PSYCHOPATHOLOGY

Muscular tensions in mental pathology are not always as popularly expected. In schizophrenia, traditionally said to be emotionally withdrawn and unresponsive, Landis and Hunt[30] found (a) the same general startle pattern as in normal persons, (b) strong responses more prevalent, particularly among catatonic persons, and (c) more extreme and more elaborate secondary behavior. Malmo, Shagrass, Belanger, and Smith[40] studying the muscle tensions of normal and neuropsychiatric persons (psychoneurotic, acute psychotic, and chronic schizophrenic patients) doing a simple mental task (judging sizes of circles) found muscle tension definitely higher in the patients, and also much disorganized muscle-action potential.

(Systolic blood pressure also was higher in the psychoneurotic and acute psychotic patients than in normal persons.) This disorganized muscle-action potential is of unique concern to prosthetic dentists. Since the masseter muscles are especially responsive, they probably are particularly susceptible to disorganized activity. Herein may rest much of the genesis of malocclusion and of the temporomandibular syndrome.

MUSCULAR TENSIONS IN OTHER ATYPICALS

Generally, muscle tensions in psychotic persons are exaggerated over those of neurotic individuals, as are those of neurotic over those of normal persons, and abnormal persons manifest disorganization as well. In hypnosis, muscle tensions are appropriate to the hypnotic state and to the suggestions given. In organicity (epilepsy, spasticity, and so forth) they are influenced by the organic impairment as well as by personality. And quite often disorganization of muscle tension, as in spasticity, is mistaken for excess of tension and personality disorder.

HYPERTENSIONS IN SMOOTH MUSCLES

This discussion has focused upon tensions in the skeletal muscles. The smooth muscles have been neglected, not because they are considered less important but because less is known about their tension states. Conceivably, muscle tension disorganization and/or excess in smooth muscle tissue may be more disabling and more lethal than hypertension in the skeletal muscles. If this is the case, it would explain many of the diseases of the circulatory, digestive, and urinary systems which do not readily appear to result from bacterial infection, faulty nutrition, or physical trauma. Perhaps the researches projected and now under way will answer many of these questions. It is to be hoped that the studies of heart diseases, presently much publicized and rather liberally supported, will not neglect muscular tensions and psychologic correlates.

ORIGINS OF MUSCULAR HYPERTENSION

Excessive muscle tension may arise in at least the following ways:

1. It may be genetic to the neurophysical structure. There is reason to believe that some individuals are predisposed from birth (by hereditary or environmental factors, or both) to muscle hypertension and neurologic imbalance. The hyperexcitability of some human beings, with concomitant excess of muscle tension readily recognizable almost from birth, and with no apparent organic disease or injury, gives weight to this view. Such individuals, we expect, would under no circumstances adjust well to the ordinary stresses of life situations. For them, very favorable (protective) conditions are essential. Removed from such protection they become incapacitated.

2. Muscular hypertension may be a conditioned-response reaction. The nature of the response, and the muscles most seriously involved, depend upon the nature of the reaction to the original stimulus evoking the response. The conditioned response is never as strong as the original response. It must be re-

established in some fashion or it suffers extinction. Apparently all higher neuromuscular systems are susceptible to it. Extinction is rapid in normal persons removed from the conditioning situation and must be reconditioned to again be operative. There is justifiable suspicion that the abnormal individual, the neurotic person, for instance, by some obscure methodology, maintains a muscle tension response conditioned by an unpleasant experience to a secondary, innocent element of the unpleasant-experience situation. He may maintain a hatred for or suspicion of an innocent bystander in a situation in which he was embarrassed or frightened. In some manner he perseverates the unpleasant experience and the conditioned muscle tensions beyond all normal expectancy.

3. Muscle hypertension may be a simple, learned, habitual response, and without mental pathology. The outthrust jaw, the jaws tightly clamped, the off-balance swagger, and even a pronounced limp may be imitations of an adored father or some other hero figure. Some malocclusions may be of this origin. That they are not more frequent and more severe is probably due to ready release of muscle tension by these "habit-bound" individuals during periods of relaxation, especially in sleep, and to the fact that their tensions are less extreme than in many mental pathologies.

4. Extreme, prolonged and disorganized muscle tension may be inextricably associated with psychic conflict. The individual may believe, yet doubt his belief; yearn for success, yet be afraid of failure; hate an associate, yet fear offending him; loathe a spouse, yet fear the consequences or expression or even admission of that loathing.

Lauria,[31] a Russian psychologist, was one of the first systematic students of human conflict. In one experiment, he produced gross hand tremor simply by altering the tempo (slowing the speed) with which his subjects had become accustomed to compressing a pneumatic tube in synchronization to words spoken rhythmically. In another experiment, hand tremor, stumbling speech, and reported failure to hear followed sudden change from the use of Russian to English and English to Russian in bilingual subjects.

The muscle tensions of both human beings and animals in similar conflict situations have been studied at Yale University.[42] Muscle spasms and catatonic states have been induced by Maier, Glaser, and Klee,[34-39] in laboratory rats in conflict situations. Similar behavior disorders (excesses and disorganizations of muscle tension) have been evoked in other laboratory animals (horses, dogs, pigs, etc.) by what appear to be conflict situations and even by unusually high tones, jingling of keys, and so forth. Hovland and Sears[18] produced motor blocking with excessive tension in human beings in conflict situations. Similar results were obtained by Barker[1] in 10-year-old boys in a conflict situation involving the choice of liquids.

MUSCULAR TENSIONS AND THERAPY

When we come to the question of therapy—the release of and normalizing of muscle tensions—we open a forum for controversy. Theories, claims, and counterclaims are in violent apposition. Jacobson[21] proposes relaxation through prolonged training as the most effective and, in many instances, the only really

effective cure. Yates[56] found that excessive muscle tension could be discharged and prevented by conditioning the patient to recall pleasant experiences in times of stress. Rogers[46,47] propounds nondirective therapy in which the patient discusses his problems, if and as he wishes, in the presence of a neutral, noncommittal counselor. Thorne[54] maintains that much therapy must be directive. Some maintain that insight is essential to cure, despite failure to find direct relationship between self-understanding and adjustment. Some recommend catharsis as the only permanent cure. The electroshock enthusiasts advise this method as quick, safe, and effective. The hypnotherapists expound another doctrine. Christian Science offers suggestibility. The religionists advocate a return to God; the anti-religionists, release from superstition. Some therapists use scribbling, some play, some fingerpainting, some nudism, some escape from sexual inhibition. Then there is dianetics with its fabulous claims to release from tension through recall of all life (including prenatal) experiences.

Out of all this confusion come a few incontrovertible findings: (a) Anything that provides release of muscle tension and that prevents its rise and maintenance at damaging levels is conducive to mental and physical health. (b) Experts in therapy (those with professional status) from widely differing schools of thought are more like each other in their methods than they are like nonprofessional therapists in their own disciplines.[14] Regardless of how professionally-trained therapists theorize, they are very much alike in their relationships with patients.

We know woefully little about what constitutes therapy, what happens in therapy, the results of therapy (some maintain there aren't any), and the part that repression of emotional response or conflict over emotional expression plays in creating abnormal muscle tensions. Nor do we know much about the therapeutic value of pleasant, uninhibited emotional response (laughter, frivolity, sensuality, and so forth) in dissipating and preventing muscular hypertension.

Much of what is credited to therapy results directly from the patient's release of and freedom from muscle tension in the presence of the therapist. Perhaps the dentist's greatest opportunity as a therapist is in providing the patient with opportunity to release muscle tension normally in an environment in which he feels secure and from which he can carry a feeling of security and confidence. However, this does not obviate the need for alleviation of pain and removal of actual physical stress. Avoidance of excessive muscle tension is well-nigh impossible for normal individuals in extreme pain. Add much anxiety and it is seldom even a remote possibility.

There is no readily available evidence that the chronic neurosis of long standing is ever cured. Apparently its intensity is reduced. Perhaps the neurotic individual learns to live with his neurosis, and it may be that we learn to live with him so that we cease to aggravate his tensions. If he acquires much insight he learns that not all his suffering is due to pain.[21] But a neurosis at maturity seems pretty well established as a way of life. Perhaps its ideational content and muscle-tense states are impinged on a constitution peculiarly susceptible to them. Demonstratably, many chronic neurotic persons are not as muscle-tense

as are many individuals who are not neurotic. Neurosis is characterized by unhappiness and incapacitation as well as by heightened muscle tension.

Extended treatment by psychotherapy in dental practice is beyond the scope of this paper. However, this area should be explored by all dentists, with a preventive as well as a curative approach. The newer dentures with sharper cutting edges illustrate one way in which stress can be reduced. Improved lighting of dental offices is in keeping with Ryan and associates'[48] findings on the effects of glare. There must be many others. It may be, as Block and Harris[3] intimate, that severe dental pathology with abnormal muscular tension correlates is scarcely amenable to treatment without psychotherapy. Perhaps the patient comes too late—when physical pathology is far advanced or when muscle tensions are too firmly established. This is unexplored territory. It is yours by right of discovery. However, utilization of many techniques and skills normally outside your immediate fields of interest may be necessary to much progress. It seems unlikely that psychologists will learn enough about dentistry to make much direct contribution in this area. A more reasonable expectancy is that dentists, sensing the need, will acquire psychologic knowledge pertinent to their specialty and of use in their researches.

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THE MANDIBULAR IMPLANT DENTURE

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SINCE Paul Revere constructed dentures for George Washington, many techniques have been developed and used by the dental profession. While they may differ widely in the approach to the problem, reasonably satisfactory dentures can be produced by using almost any one of these techniques if the patient possesses normal edentulous ridges. However, there are conditions, brought about by resorption, which present extremely difficult problems for the prosthodontist. In many cases of extreme resorption, the construction of satisfactory mandibular dentures becomes almost an impossibility.

The plight of patients with such ridges aroused my interest and sympathy, and in May, 1944, original research was begun to see if the problem could not be solved by the use of some type of a mandibular implant denture. I felt that if such a technique could be perfected many patients should be able to wear dentures with peace and comfort, who would otherwise be condemned to go edentulous the remainder of their days.

Implantation is not new to the medical and dental professions. Some of the pioneers were Maggiolo of Paris in 1809, Rogers of Paris in 1845, Harrison of California in 1887, Edmunds of New York in 1889, Bonwill of New York in 1895, Paye in 1898, and more recently Greenfield[1] in 1913. These men used everything from lead to iridioplatinum. There were failures in these implants due to erosion of the metal or to the mechanics involved, as in the case of Greenfield.

The tolerance of bone to certain metals varies greatly. The investigation of Stuck[2] showed that cobalt, chromium, and molybdenum alloys were inert when implanted in bone.

PROCEDURE

The dentist who attempts the construction of the implant denture should be well experienced in the construction of full upper and lower dentures, and he should work in close cooperation with the oral surgeon. The first patient, carefully chosen, should be in good general health and have a good mental attitude.

The mandible should be roentgenographed thoroughly to determine its physical characteristics. At the first appointment, roentgenograms are made of the following areas: the relation of the alveolar ridge and external oblique ridge to the anterior border of the ramus of the mandible (buccolingual and occlusal views

Read before the Academy of Denture Prosthetics, New Orleans, La., March 20, 1952.
Received for publication April 8, 1952.

are required on each side), and the relation of the mental foramina to the crest of the ridge on both sides. The roentgenograms help to determine the design of the framework of the implant.

The procedure for the second appointment is to secure primary impressions of the upper and lower arches. Make sure you use plenty of compound in the lower tray in order to record all of the anatomic landmarks of the mandible. Be sure you get a good anatomic impression of the mylohyoid ridges and the external oblique ridge. Use your regular impression technique on the maxillary arch. From this point on, proceed as if you were to construct conventional upper and lower dentures. Try the wax setup in the patient's mouth. After the occlusion and the esthetics are satisfactory, lay the setup aside. Proceed this far in the construction in order to establish the plane of occlusion so it can be used in the construction of the implant.

THE TEMPLATE METHOD

The contour of the mandibular ridge is determined by the template method. On the lower stone cast, duplicate the cast, thereby preserving the original cast on which the framework of the implant will be designed. The outline of the framework of the implant is made in this way. Make the distal extension of the implant about 10 mm. distal to the location of the second molar tooth. From this point, a line is drawn buccally to the external oblique ridge; lingually the line is

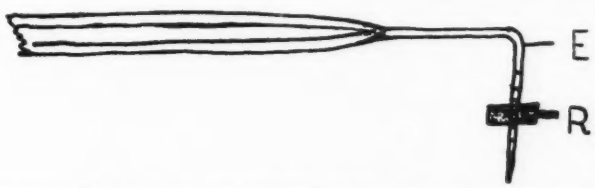


Fig. 1.—The mucosa depth gauge. An explorer is bent as right angles (*E*) and callibrated in 0.5 millimeters. *R*, Rubber marker.

drawn to the mylohyoid ridge. For the buccal outline, draw a line anteriorly above the mental foramen and down labially onto the recess of the chin. Lingually, follow the crest of the mylohyoid ridge anteriorly until you reach the first molar region. Continue the line forward above the attachment of the genioglossus muscle. The outline of the implant varies greatly in different cases. Take as much advantage of all of the cortical bone area of the mandible as is possible. Place the template over the outline drawn on the cast. With a No. 6 round bur, make holes in the template along the border of the drawing which can be seen through the clear template. This is done on the duplicate cast. Make the holes about 6 mm. apart. Now make holes along the crest of the ridge.

Make a large drawing of the template with marks to indicate the locations of each of the holes in the template. This drawing should be about 8 by 8 inches. Make a "mucosa depth gauge" from an old explorer. The point of the explorer is bent at right angles to the handle. The shank of the point should be about 1 in. long and provided with ½ mm. calibrations. This is done best by first painting the shank of the instrument with fingernail polish. Then, after it is dry, the

calibrations are marked on the shank and, with a sharp chisel and mallet, cuts are made into the shank (Fig. 1).

MEASURING TISSUE THICKNESS

Anesthetize both sides of the mandible at the next appointment. Place the template in the patient's mouth and hold it securely in place. The "mucosa depth gauge" point is pushed through a small piece of hard rubber. Force the "mucosa depth gauge" through each of the holes until it touches the bone (Fig. 2). Measure the thickness of the tissue as registered by the rubber sliding up the shank of

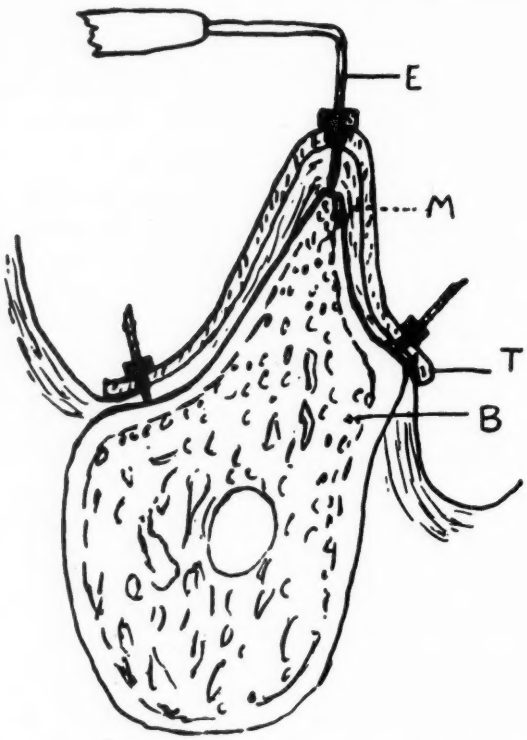


Fig. 2.—Cross section of the mandible, mucosa, and template. *B*, Bone. *T*, Template. *M*, Mucosa. *E*, Mucosa depth gauge measuring the thickness of the soft tissues plus the thickness of the template.

the gauge to expose the calibrations. Of couse this reading will represent the thickness of the mucoperiosteum plus the thickness of the template. Each measurement must be recorded at the mark on the drawing of the template which corresponds to the aperture through which the measurement is made. While taking the measurements along the crest of the ridge, be sure the point does not slip down the side of the ridge, as this would indicate a false depth. This can be avoided by feeling the crest with the calibrated "mucosa depth gauge."

MODIFICATION OF THE CAST

After the depths are registered through each hole in the template and recorded, place the template on the stone cast. Guide holes are then made in the

cast through the holes in the template. To make these holes, use a No. 6 round bur which is marked with 0.5 mm. calibrations in a straight handpiece. Place a pencil clip on the contra-angle receptacle on the grip of the handpiece. The pencil-clip head is adjusted to the same calibration for each hole as that indicated by the record of the tissue depth which was marked on the large drawing of the template (Fig. 3). Holes are drilled into the cast to the depth registered by the "tissue

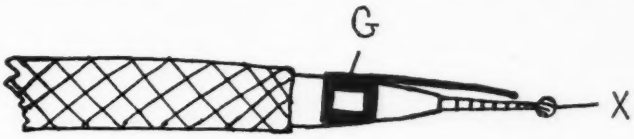


Fig. 3.—Straight handpiece with a pencil clip marker (*G*) and a No. 6 round bur with 0.5 mm. calibrations (*X*).

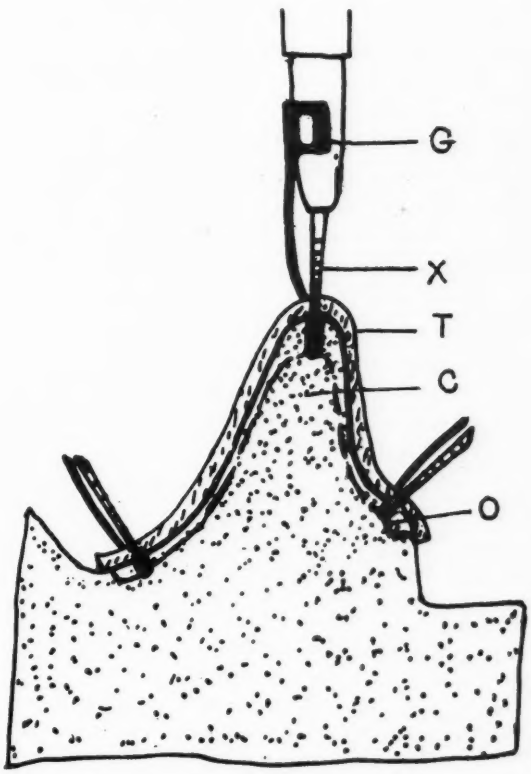


Fig. 4.—Modification of the cast to the contour of the bony surface of the mandible. *G*, Pencil-clip marker. *X*, Calibrated bur. *C*, Cast. *O*, Portion of the cast which is cut away.

depth gauge" (Fig. 4). Use a scraper or a large heatless stone to scrape or grind the cast down *nearly* to the depths of the holes. Be sure not to remove the stone to the complete depth of the holes. Leave a fraction of each hole still showing on the cast after the trimming is done. Outline the implant on this cutaway cast. Be sure to make places for two screws on the recess of the chin. This cast then is sent to the laboratory to have the implant cast in Vitallium (Fig. 5).

LABORATORY TECHNIQUE

The laboratory technician should be instructed in advance on the construction of the implant frame. Place the lower setup over the cutaway cast to determine where the first bicuspids and second molars will be located. This location may have to be varied according to the physical structure of the bone. Measure the length of the four teeth from the occlusal surface to the tissue surface of the base of the baseplate under each tooth, and add the thickness of the mucosa in that area, then subtract 0.5 mm. Write these measurements on the cast in their respective places. The framework of the implant including the screw head recesses is first designed in wax on the refractory cast. The teeth to be a part of the implant are then carved in wax, and placed in their respective positions. Porcelain or acrylic facings are placed on the first bicuspids. Make places for rest lugs in these implant abutments for the removable portion of the denture. The abutments should be parallel to one another. The implant frame and abutments are cast in noncorrosive metal (Vitallium). Do not polish the framework of the implant, but leave it rough from sandblasting. Polish the abutments.

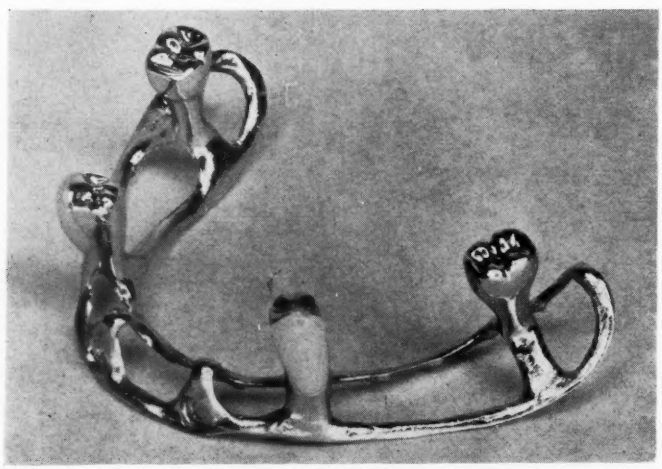


Fig. 5.—The mandibular implant ready for insertion.

After the implant frame has been made, place it on the stone cutaway cast. Cover the frame with 4 mm. of wax. Make the framework for the removable portion of the implant denture to fit the implant frame. Set up teeth to occlude with the upper denture. The lower partial denture is then processed in acrylic. Of course the base of the acrylic will be about 4 mm. short of the ridge. This is corrected by relining after the ridges heal.

SURGICAL PROCEDURE

Procaine is used to obtain block anesthesia of the mandibular, lingual, and long buccal nerves on both sides. Start the incision just anterior to the pear-shaped retromolar pad on each side. Continue the incision anteriorly buccal and labial to the crest of the ridge. Before the mucoperiosteum is laid back, the mental

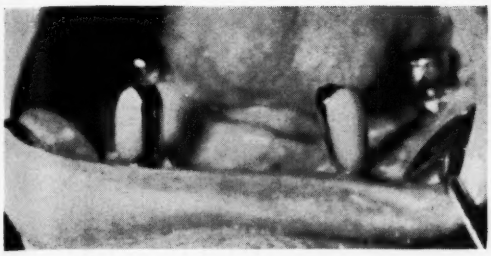
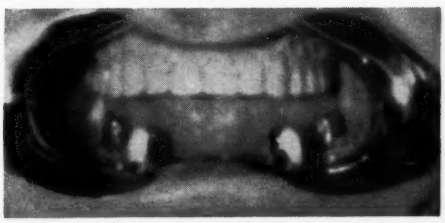
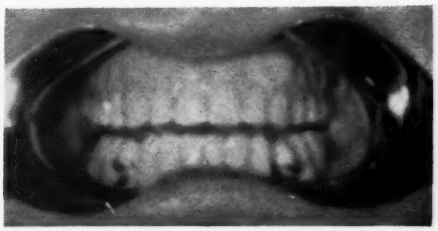


Fig. 6. Fig. 7.

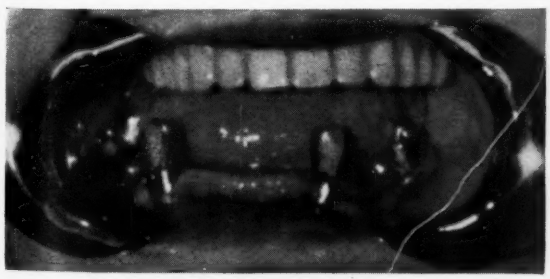
Fig. 6.—The implant in position.
Fig. 7.—Roentgenogram three years after the implant was inserted. The patient was 70 years of age.





A. *B.*

Fig. 8.—A frame type implant two weeks after insertion. Note rapid healing. The patient was 55 years of age.



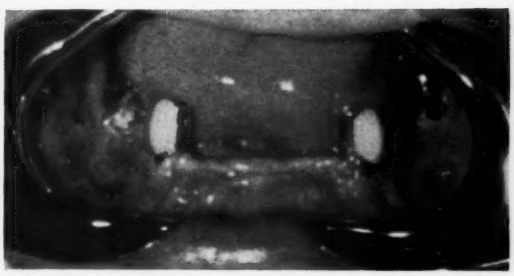


Fig. 9. Fig. 10.

Fig. 9.—A frame type implant eight days after insertion.
Fig. 10.—A frame type implant eight months after insertion. Note the close adaptation of the mucosa to the implant abutments.

Fig. 11.—Upper implant three months after insertion. The patient was 23 years of age.

foramina should be located from the radiograms, and a short hypodermic needle inserted in each foramen. This is done to avoid cutting the nerves and blood vessels. Place the implant on the ridge to determine how far back the mucoperiosteum should be retracted. The dental assistant stands by with the aspirator to keep the area free from blood. Place the implant under the mucoperiosteal flap. Use a bone bur slightly smaller than the bone screws to drill a hole in the bone at right angles to each screw head receptacle on the implant. Drive the screws to place but do not tighten them down firmly as they may raise the posterior part of the implant. Place penicillin powder in the incision, and suture the tissue as closely as possible. Use a mattress continuous suture as it will not pull through tissue. Tie the end of the suture to the second molar abutment of the implant, then pull the tissue edges together with continuous suture. The only postoperative pain experienced by patients thus far has been from the pulling of the sutures. For the relief of this pain, give 0.5 grain of codeine the first night.

The removable partial denture is placed in position after suturing is complete. The full upper denture setup is placed in the mouth and the occlusion is checked and corrected. Process the upper denture and insert it within the next few days (Figs. 6-11).

The patient is instructed not to exert any force on the implant denture for several days. After the sutures are removed and the mucosa has returned to normal, the removable partial lower denture is relined.

CONCLUSION

The dentist who constructs an implant denture should be well qualified in the field of prosthetics. He should also work in conjunction with a good oral surgeon while the implant is placed in position.

The implant is recommended only for patients whose mouth conditions make it practically impossible to build a comfortable, stable conventional lower denture, or for patients who have a deformity or injury of the mandible so a complete denture cannot be made satisfactorily.

Vitallium is very favorably tolerated by the bone and mucosa, even though the implant is not completely covered by tissue. There has been no infection of the mucosa or the bone in any of the patients thus far.

The psychologic effect on these patients is tremendous after they are able to masticate in comfort. They seem to take a new lease on life.

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VERTOCCLUSION

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THE principal objective of full denture prosthesis is the re-establishment and maintenance of normal masticatory processes. Since efficient function hinges on harmonious occlusion and articulation of the artificial teeth, it is obvious that a return to normal function is one of its primary aims. When the restorations have been inefficient for any reason, they have been accompanied in many cases by intermittent pressure atrophies, temporomandibular derangements, and gastric disturbances.

Bad results emanating from maloccluded dentures are of paramount importance to the patient. It is incumbent upon us to correct these causative factors when they are recognized. The necessity for their correction is often unrecognized at the chair and more often in case planning. As a consequence, many cases meet with disaster before the impression stage has been reached. Plans for the recapture of vertocclusion should be a standard part of case planning. Case planning presupposes a thorough knowledge of roentgenographic and pre-extraction cast interpretation.

Because of the ready accessibility of the mouth, the casts, and roentgenograms, they add a three-dimensional aspect to diagnosis, and may be used to prognose favorable and unfavorable ridge forms with reasonable accuracy.

In so far as a working diagnosis is concerned, any adverse condition can be described as a functional disturbance not to be considered by itself alone; instead, it should be related to the restorative problem, and specifically to the recapture of the correct plane of occlusion and the correct vertical dimension which is now recognized as a fickle and variable dimension. Recognition of these variations requires but a glance at the roentgenograms, pre-extraction casts, and the mouth.

Static vertocclusion is seldom met with, in artificial denture patients, as hypo-ostosis usually predominates this field in which the interalveolar space is incremental. Increments are directly related to atrophic changes in the bone. The stages of atrophic changes are measurable in millimeters, symbols that are understandable. Aside from contributory mechanical factors, such as intermittent pressure atrophies resulting from opened or closed vertocclusion, there probably has not been a single one but a combination of causes that have proceeded in a slow and mysterious cycle to accelerate these variations. Included are endocrine and vitamin deficiencies. Attempts at calcium fixation at times lead to gratifying results.

Received for publication Feb. 4, 1952.

At the chair, good surgical procedures, followed by orderly prosthodontic steps wherein pre-extraction casts and equalized vertocclusion have been emphasized, will tend toward calcium fixation and add years to the usefulness of the restorations. Without doubt, the long-standing work of Bennett[1] in his studies of the temporomandibular movement, coupled with the present-day search for its missing coordinates—the correct interalveolar space and the correct plane of occlusion—will have a far-reaching effect on our present-day knowledge of lesions affecting the alveolar ridges and the temporomandibular joint. With a realization of this situation, the following illustrations are offered as a reasonable basis

Fig. 1.—A roentgenologic study of hyperostotic bone of a patient 36 years of age. Compare with Figs. 2 and 3.

for the interpretation of roentgenologic evidence of porotic malacia of bone as it pertains to atrophic changes in the alveolar ridges. These changes may increase the vertical dimension in one instance, and effect it in another by sculpturing the ridges into grotesque hypertrophic forms that require surgical intervention for good prosthesis.

For clinical consideration and observation, there are two distinct types of alveolar bone according to its relative density. These are classed as hyperostotic and hypo-ostotic.

In the hyperostotic type (Fig. 1), attention is directed to the appearance of the trabeculae as an index to density. The well-filled trabeculae (storehouses of calcium) seem to merge with their network, thus imparting an appearance of solidity which is its chief characteristic.

In Figs. 2 and 3, the reticular outline of the trabeculae of the bone stands out in relief, and imparts the appearance of softness and instability to the bone. The greater number of edentulous cases falls into this bone type. Atrophy will progress to a greater degree, and will affect the stability of the dentures. At the same time, it will increase the vertical dimension and make its recapture difficult.

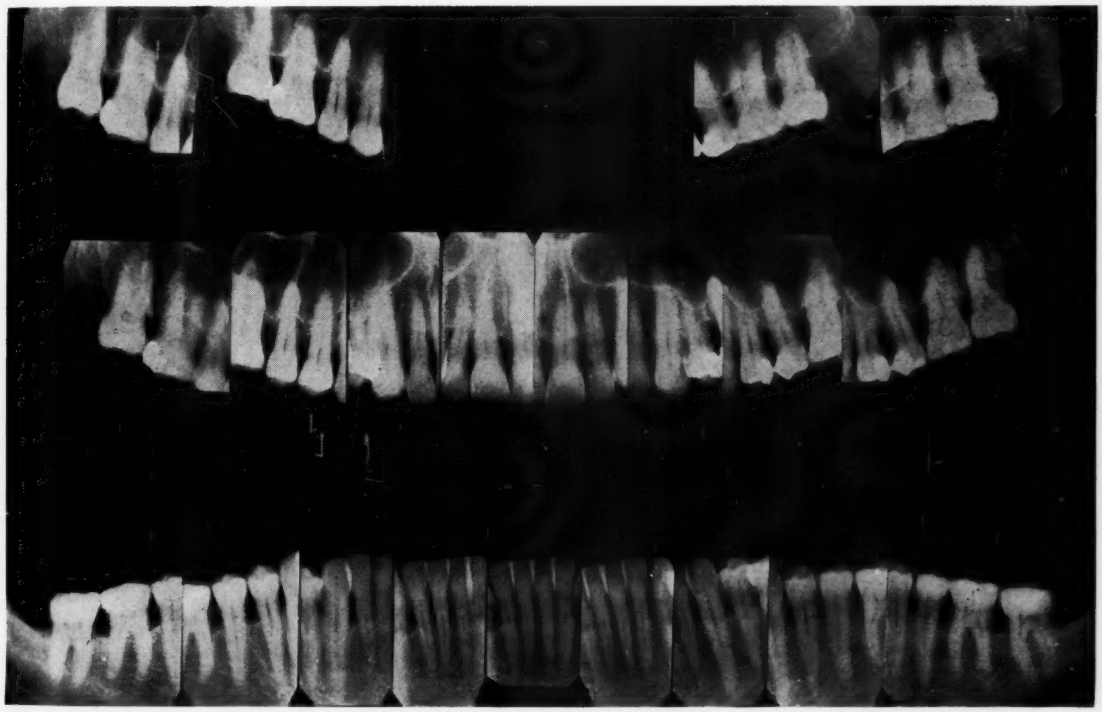

Fig. 2.—A roentgenologic study of hypo-ostotic bone of a 36-year-old patient. The interalveolar space is increasing while teeth are still present.

VERTOCCLUSION

Vertocclusion implies: (1) that the condyles are in their correct positional relationship with the meniscuses with which they articulate; (2) that the teeth are in centric occlusion, and (3) that the specific distance, measurable in millimeters, which is the normal interalveolar space for that particular person, exists between the crests of the maxillary and mandibular ridges in the median line. The interalveolar space varies in different individuals; therefore no average can be struck. The occlusal plane remains constant. The interalveolar space alone undergoes change because of atrophic factors. The identity of these coordinals was hidden from Bennett[1] and has remained lost to confuse present-day prosthodontists.

Taken collectively, the roentgenograms offer a composite picture of the original interalveolar space undergoing change while teeth are present. They

thus offer the prosthodontist a challenge to recapture the extant vertocclusion when the teeth are to be restored following their loss.

The roentgenograms mark the transition of the crest of the alveolar bone from tooth cervix to root apex, a phenomenon that will continue after the teeth are lost. In part, they shed light on the changing or variable vertical dimension. They also disclose reasons for remaking and rebasing artificial dentures, and the use of denture adhesive powders. They have added significance in that they will bring about new awareness to the transitory nature of alveolar bone and its relationship to the missing coordinals of the Bennett movement.

Fig. 3.—A roentgenologic study of hypo-ostosis in a patient aged 50 years. The bone crest level has reached the apices of the maxillary incisor roots from its original elevation at the cervical end of the tooth. The present distance between the crests of the two ridges with the teeth in occlusion will be the extant interalveolar space when the teeth are removed.

Vertocclusion unquestionably is the axis around which prosthodontia revolves. Any deviation from it can lead to disturbing imbalances. A disrupted vertocclusion following the staggered loss of natural teeth leads to temporomandibular derangements which require splints for correction.

In the field of operative dentistry, a single high, hard gold filling can disrupt its nice balance and adjustment.

In the restorative field involving fixed and removable partial denture restorations, an increased vertocclusion makes a formidable contribution to disturbances

in the temporomandibular joint. In fully edentulous patients, the inaccurate recapture of vertocclusion often finds the patient in consultation with ear specialists for relief of pain, and thence to the oral surgeon whose recourse is the injection of sclerosing fluids and other drastic forms of surgical treatment.

ALVEOLAR BONE TYPES AND VERTOCCLUSION

There are three general categories of atrophic change in alveolar bone which affect the stability of artificial dentures by increasing the height of the interalveolar space. The first of these involves hypo-ostoses and concurrent loss of the bone and soft tissue. In the oral cavity the clinical picture is one of a glovelike fit over the superior border of the body of the mandible, the alveolar process having been completely absorbed to the elevation of the mental foramina, the mental process, and the genial tubercles. The superior border of the body of the mandible now presents a concave surface for the reception of the denture.

A similar picture presents itself in the maxillae where atrophy has continued to the floor of the nasal cavity. In such cases of senile atrophy the interalveolar space attains a length of thirty-four millimeters.

A second form of atrophic change is described as osteodystrophia fibrosa. Its chief characteristic is the complete loss of the alveolar bone and the retention of the soft tissue comprising the ridges which become hypertrophied and extend vertically and lingually to assume grotesque forms that decrease the interalveolar space.

The third bone type is termed hyperostotic. Its chief characteristic is density which does not lend itself readily to atrophic change. When it does, the alveolar process takes the form of a thin, high, sharp ridge in the mandible and in the maxilla, which at times requires surgical interference.

Reference to bone types is germane to this discussion of vertocclusion. Its significance is doubled because of the occurrence of varying degrees of atrophic changes that add to the interalveolar space. This increment becomes the extant interalveolar space when the teeth are lost. To assure mechanical success it must be recaptured with precision.

The interalveolar space and the plane of occlusion are established by the eruption of the mandibular and maxillary first molars. The former is variable; the latter is invariable throughout the life of the patient. Hence the importance of an acquaintance with the clinical behavior of alveolar bone to students of prosthodontia.

VERTOCCLUSION AND THE GOTHIC ARCH TRACING

The Gothic arch tracing is used not to record habitual masticating movements but to record the movements of the mandible that are most easily recorded.

The apex of the Gothic arch tracing with the path-marker pin in position implies centric jaw relation. However, if the plane of vertocclusion were established, not in its normal centric position but in an opened or closed relation to

it, the Gothic arch tracing and the check bites used in collaboration would be valueless.

It has been found by careful workers that correctly established vertocclusion mounted on a Simplex articulator will obviate the use of Gothic arch tracings, check bites, and the adaptable articulator. Success is further enhanced with 20 degree teeth used in conjunction therewith.

VERTOCCLUSION AND THE CURVE OF SPEE

Without a single exception, the natural order of the curve of Spee is wholly abrogated in the prosthetic scheme. Thirty-two natural teeth are replaced by twenty-eight artificial substitutes, the cusps of which have an average of 20 to 30 degrees. The undulations of the anteroposterior curve and its transverse coordinal must be reduced to a leveled plane; contact of the incisal edges of the mandibular incisors with the lingual surfaces of the maxillary incisors is lost. Touching on this phase, Gysi[2] has stated, "In edentulous patients, the forward and downward movement of the incisor point is the only movement that is lost when the maxillary incisors are lost." Therefore, we are free to vary this sagittal inclination of the incisal path according to engineering principles in such a way as to secure perfect interdigitation of the teeth in all movements, and thereby increase the stability of the dentures and lessen the destructive horizontal pressure on the alveolar ridges.[3]

VERTOCCLUSION AS A MEASURABLE FACTOR

An indefinable haze has enveloped the missing coordinates of the Bennett movement. Bennett acknowledged this, and Gysi recognized the discrepancy with misgivings. Gysi[4] stated, "The fourth movement of the incisor point, the opening movement, we can ignore somewhat, if we do not alter in the articulator the height of the bite, which we have determined in the mouth of the patient." Ambiguity surrounds his method of determining the height of the bite (interalveolar space). He further stated, "It is rarely if ever practicable for prosthetists to make artificial dentures which restore the original height of the bite." His method of gauging the height of the bite was not clear, when he said, "In all cases, the height of the bite was tested by facial expression and the ability to pronounce clearly." (A statement which is no reflection on the master.) That it is incumbent upon us of the present day to clarify this one point in prosthetic teaching is too strong to be denied, for no one phase of the work has contributed more to the use of denture adhesives, reliners, and rebasing materials, all of which imply failure.

VERTOCCLUSION AND IMMEDIATE DENTURES

The recapture of vertocclusion is exemplified in theory and practice at the time immediate dentures are made by mounting occluded pre-extraction casts on

the articulator, setting the incisal guide pin, removing the plaster teeth, and finishing the dentures accordingly. Here the parallel ends, for when healing processes are completed the original vertical dimension is lost because of atrophic change and subsided edema. Indiscriminate relining and rebasing increases the height of the interalveolar space in these dentures by three or more millimeters. Without extra pre-extraction casts as controls, vertocclusion is lost and, in ineffectual attempts at its recapture, a vicious cycle ensues. Vertocclusion is adversely affected by poor impressions, improper surgical preparation of the ridges, faulty articulation of the artificial teeth, unfavorable planes of remaining natural mandibular teeth, osteomalacic diseases, and loss of weight by dieting or from other causes.

VERTOCCLUSION AND HYPEROSTOSIS

A clinical study of hyperostosis, supplemented by roentgenologic findings, shows little tendency of the alveolar process toward absorption.

Hyperostotic bone hugs the cervices of the teeth intimately; unlike hypoostosis, it does not respond readily to atrophic influences.

Because of this physical characteristic, abrasion of the incisor teeth involves their crowns almost to the cervices without infringing the process which supports them. The original interalveolar space is thus decreased. The temporomandibular articulation and muscle tone adjust to this gradual decrease, which over a period of years becomes fixed as low as eight millimeters of interalveolar space.

When the teeth are lost, the problem becomes one of not recovering the original interalveolar space but one of recapturing the extant vertical dimension. Its accurate recapture necessitates alveolectomy. Three millimeters or more of both processes must be removed to compensate for the thickness of the baseplate material and the ridgelaps of the teeth. Increasing the interalveolar space in these patients is contraindicated.

CONCLUSION

Vertocclusion is a combined word form, meant to describe the exact point of intersection of the vertical plane by the plane of occlusion, and/or the combination of the two planes as a single unit.

With the teeth occluded, the vertical location of the plane of occlusion, coupled with the interalveolar space or the vertical dimension in the median line, is the terminus, or the anterior limit of the Bennett movement, in the sagittal plane.

This has been a blind spot in prosthodontia. Vertocclusion should be engineered into every new set of artificial dentures.

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EVALUATION OF THE FACE-BOW

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INTRODUCTION

EARLY articles on prosthetic dentistry in which the face-bow is mentioned are, broadly, of two kinds: those in which its use is insisted on (Logan[1]), and those in which it is dismissed as a useless if harmless toy (Stansbery[2]). The difference between current literature and that of thirty years ago is merely one of degree. Whereas the subject used to be hotly debated by hostile schools of thought, the issue has now lost its emotional content, and users and nonusers of the face-bow are able to regard each other with a slightly amused indulgence which was formerly lacking. The crusading spirit and the intolerance have evaporated. This is not to say that everywhere reason now prevails; on the contrary, the issue has never really been decided.

Authors of modern textbooks and of articles in current periodical literature who mention or describe the use of a face-bow do so as a matter of course; they assume acceptance of the face-bow and no longer bother to insist on its use or attempt to describe what it achieves. With equal confidence, those in the other camp omit all reference to it. This they do without embarrassment or apology; the instrument is considered unworthy of mention.

In the actual practice of prosthetic dentistry, a similar freedom prevails; whether a prosthetist does or does not use a face-bow will be found to depend on such fortuitous circumstances as whether or not he was taught to use one in dental school or, if he is impressionable, whether or not one was used at the most recent and spectacular prosthetic demonstration he witnessed.

Since we have all seen efficient dentures constructed with and without a face-bow, we may admit at the outset that a face-bow is not essential to a good prosthetic restoration, in the sense that a matrix band is essential to the insertion of a good two-surface filling. But we must also start from the reasonable assumption that a face-bow is not entirely without effect on the finished result and that the matter to be elucidated is the nature and magnitude of this effect. In plain language, the question to be answered is: What does a face-bow achieve? To say that a face-bow locates the apex of the Bonwill triangle

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is not an incorrect answer to the question, but it merely prompts another: What is the Bonwill triangle and why is the location of its apex supposed to be important?

If we can succeed in explaining what a face-bow does in terms of its practical effect on prosthetic restorations, we will be in a position to decide dispassionately whether or not we should use one. The following discussion will, therefore, be largely devoted to showing precisely what may happen when a face-bow is used and when it is not used, and to assigning quantitative measures to the differences observed.

WHAT A FACE-BOW DOES

Broadly speaking, a face-bow records in three planes (anteroposterior, lateral, and vertical) the position of the maxilla in relation to two points on the cranium, namely, the glenoid fossae. More specifically, it relates the maxilla to the intercondylar line, and hence, it is commonly assumed, to the horizontal axis about which opening movements of the mandible take place. Graphic records of mandibular movements and radiographic investigations of the temporomandibular joint have repeatedly shown that this assumption is well founded, and that in normal subjects and for small opening movements the horizontal axis of rotation does in fact pass through the condyles. It is true that in wider opening movements the axis becomes progressively displaced downwards. But this is of anatomic rather than prosthetic interest; it must be emphasised that in restorative and prosthetic treatment we are concerned with relations between teeth only when they are in occlusion or at most slightly separated.

While conceding this point, a few writers have nevertheless thought it necessary to locate, with scrupulous care, the exact position of this initial opening axis. Such a real, as distinct from assumed, axis can be found for each patient by means of a so-called kinematic face-bow attached for this purpose to the mandible instead of to the maxilla. But the search for the axis, in addition to being troublesome, is of no more than academic interest; for it will never be found to lie more than a few millimeters distant from the assumed center in the condyle itself. As is well known, this may be determined by simple palpation or by following the convention of measuring a distance of about 1 cm. anteriorly along a line drawn from the upper free margin of the tragus of the ear to the corner of the eye. If, as we are entitled to, we limit our observations to opening and lateral movements of 3 mm. at the incisors, it is obvious that a difference of a few millimeters in the location of an axis which is about 100 mm. distant from the point we are observing can have little practical effect on the arcs generated.

Of the various errors which could arise in mounting maxillary and mandibular casts in relation to the intercondylar axis of an articulator, some are so improbable or evidently of so little significance that they can be dismissed at once. Any operator who is capable of applying a face-bow symmetrically is equally capable of mounting casts symmetrically by simple inspection. The kind of error shown in Fig. 1 can therefore be dismissed as equally possible with

or without a face-bow and in either case highly improbable. It can be conceded, however, that a face-bow transfer will occasionally yield a result like that shown in Fig. 1, though in a much less exaggerated form. In such an event, it is difficult to decide whether the asymmetry is really characteristic of the patient or whether it arises from a fault in the application of the bow to the face. If it be contended that this kind of asymmetry revealed by a face-bow transfer is, in fact, an anatomic feature and as such should be incorporated in the mounting of the casts, it can be replied that the observed deviations are always small (a matter of 4 or 5 degrees at most) and that their effects on the occlusal relations of the teeth over the assumed small range of movement can be no greater than those of other but similar deviations which we shall presently investigate. A further example of eccentric orientation is well illustrated and elucidated by Swenson[3] (see his Fig. 367); but again it is of the same improbable kind as that already discussed here, and he does not assign quantitative measures to the small errors shown.

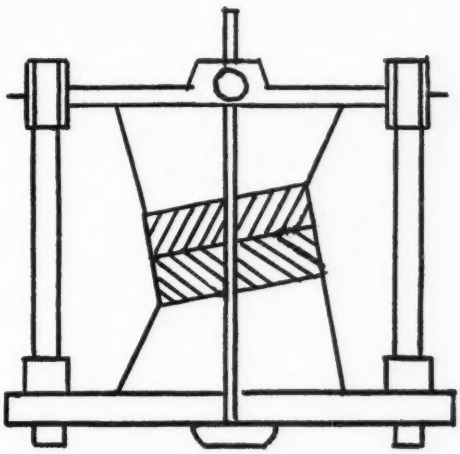

Fig. 1.—An example of an improbable error in orientation which could only be caused by carelessness and could arise with, as well as without, a face-bow.

Since they occur most frequently, and lend themeselves to a relatively simple geometrical analysis, we shall consider in detail only errors in the antero-posterior position of the casts in relation to the intercondylar axis.

First, it will be desirable to agree on the probable magnitude of the antero-posterior error which would be introduced in practice when casts are mounted without a face-bow. Every student and practitioner of prosthetic dentistry knows what the Bonwill triangle is and knows that it has sides which average 10 cm. This being so, the use of a simple pair of calipers in the laboratory is all that is necessary to mount casts always at the same *average* distance from the intercondylar line. The practicability of such an average positioning for all cases derives some support from the continued existence of a number of articulators which, by means of a simple jig or locating pin, make such a constant mounting not only possible but easy.

Those who recommend the use of a face-bow state, quite correctly, that some patients have dimensions larger or smaller than average. While accept-

ing an average of 10 cm., we must therefore concede that occasionally we will have to arrange teeth effectively for patients in whom this dimension is, for example, 8 cm. and for others in whom it is perhaps 12 cm. These figures are chosen to give what we believe to be a generous range to anatomic variations. Let us assume, then, that casts have been mounted on an articulator in a position corresponding to the average Bonwill triangle, but that the patient has, in fact, a triangle of greater than average length.

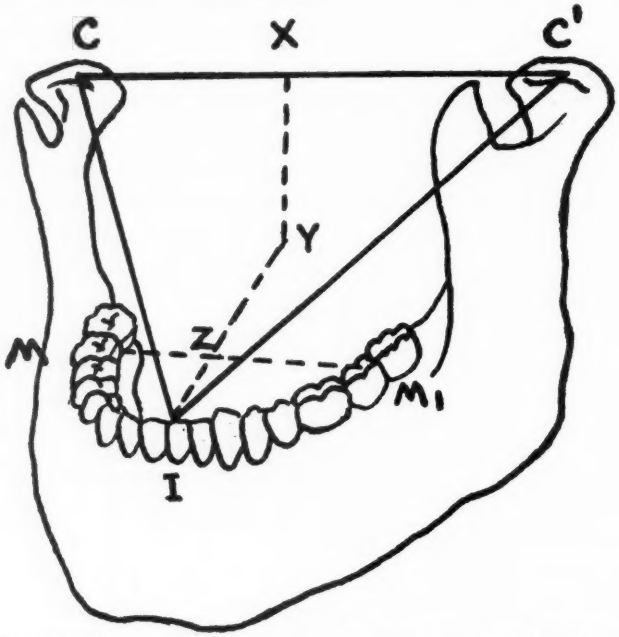

Fig. 2.—Bonwill triangle and points of reference on which the calculations in the text are based. *ICC'*, Bonwill triangle. *IMM'*, Occlusal plane. *IY*, Axis of the parabola of the dental arch; necessarily lies in the occlusal plane. The termination (*Y*) of this line is the point from which a perpendicular to *IY* meets the mid-point (*X*) of the intercondylar axis. *Z*, Intersection of *IY* and *MM'*. By geometrical symmetry, *Z* bisects *MM'*, and *MM'* is perpendicular to *IY*. *I* is the incisor point. *C* and *C'* are the condyles. *M* and *M'* are the positions of right and left second molars. In the average case, *Z* bisects *IY*.

The various planes and points of reference are disposed as shown in Fig. 2, in which the Bonwill triangle is represented by *ICC'*, and *MM'* are the positions of right and left second molars. The additional dimensions are those used in the subsequent mathematical analysis. An increase of 2 cm. in the side of the Bonwill triangle (*CI*) can be shown to be equivalent to a 2.39 cm. increase in *IY*. For simplicity in calculating the effects on opening, protrusive, and lateral relations, we have adopted a 2 cm. error in *IY*. As explained above, this error is assumed to be caused by an anatomic variation of the patient from the average, and is clearly greater than any error which is likely to be encountered in practice. We are now concerned to find out whether the error introduced into the occlusal relations of the teeth by this discrepancy is of practical dental significance. Although this is only one of the errors which a face-bow is designed to avoid, it is the principal one; therefore, if the error is found to be significant, the case for the use of a face-bow is established.

A. OPENING RELATIONS

We subscribe to the traditional view that when casts have been mounted in an articulator from centric occlusion recorded in the patient's mouth it may be hazardous to increase or decrease the separation of the casts on the articulator. The risk of error varies directly with the magnitude of the change. If such a change in vertical separation is desired, a new record should be obtained in the mouth and a new articulator mounting made. Nevertheless, the temptation to make a small change of this kind on the articulator is sometimes great, and we feel that we are not alone in having succumbed to it on rare occasions.

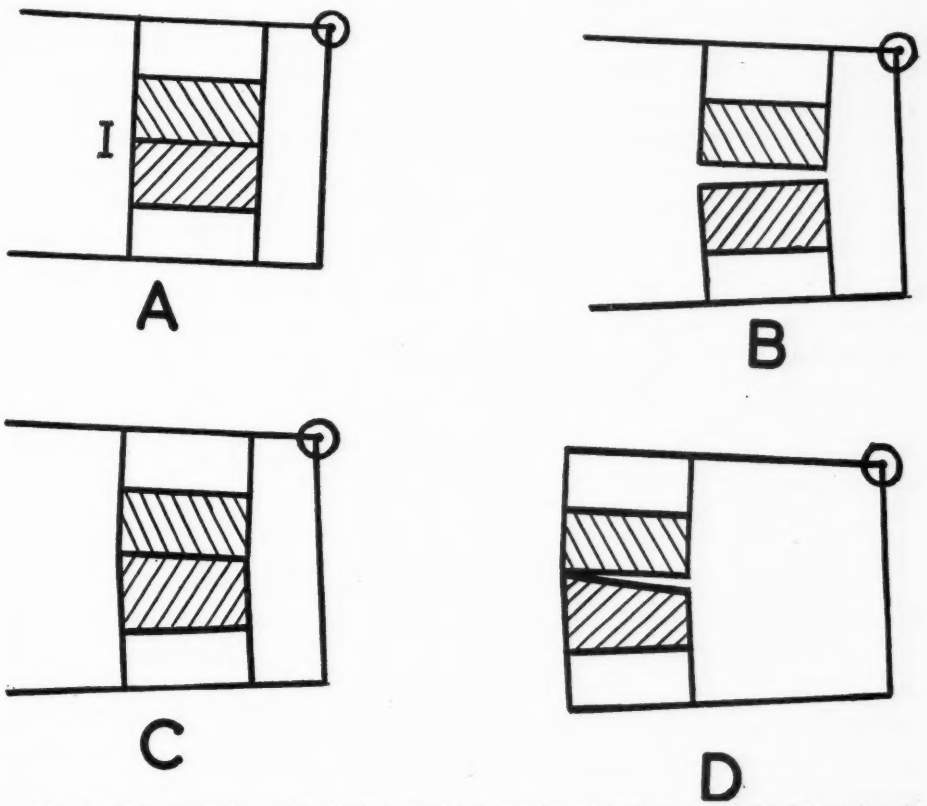

Fig. 3.—Exaggerated representation of the error in occlusion caused by increasing jaw separation in the articulator when the opening axis of the articulator does not coincide with that of the patient. The positions are identified in the text.

Moreover, those who do not use a face-bow would no doubt admit, and those who do use a face-bow would certainly insist, that a face-bow transfer will reduce if not eliminate such errors. Therefore, the effects of these changes are worth discussing. They can be illustrated simply in the manner of Fig. 3, in which it is assumed that the dentures have been mounted without a face-bow and have thus been placed too close to the intercondylar axis. In *A*, the dentures are shown as originally mounted in centric occlusion; in *B*, the jaw separation has been increased on the articulator; in *C*, the teeth have been rearranged and

brought into normal occlusion again; and in *D,* the dentures have been returned to the patient's mouth, in which they take up a position farther from the intercondylar axis. Only the incisors will then make contact when the patient closes the jaws.

To determine the error quantitatively, let us assume a practical case in which the vertical dimension at *I* has been increased on the articulator by 3 mm. If we now complete the dentures and place them in the patient's mouth (in which they are assumed to occupy a position 2 cm. farther from the intercondylar axis than they did in the articulator) we will find that the molars which were formerly in occlusion are now separated by 0.3 mm., and that to bring all teeth again into uniform occlusion it will be necessary to grind a maximum of 0.5

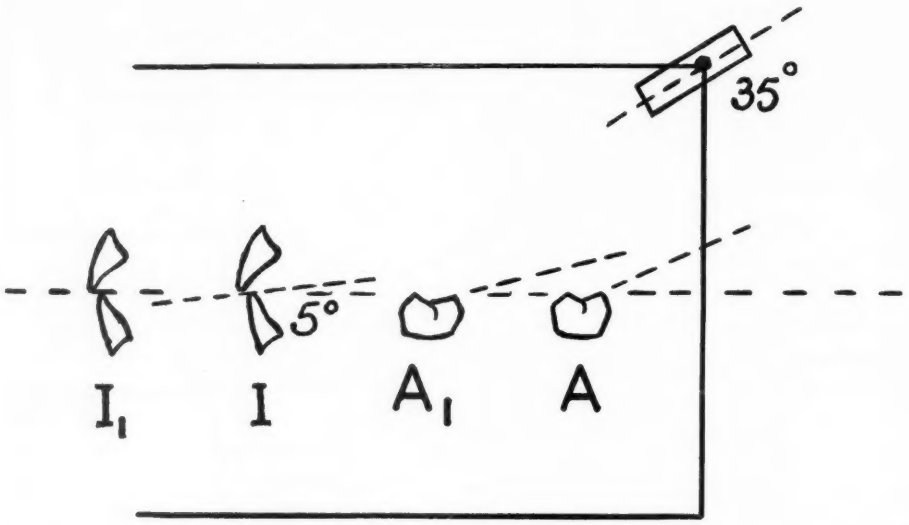

Fig. 4.—The effect of different anteroposterior positions of the molars on their cusp angles.

mm. from the incisors at *I* and decreasing amounts as we proceed backward toward *M.* In the case of full upper and lower dentures, each unit needs be ground only one-half the required amount. The maximum mutilation of each upper and lower incisor would thus amount to only 0.25 mm., or approximately one-hundredth of an inch.

Assuming that an error of this magnitude could be detected clinically, and having regard to its rare occurrence, most operators would (reasonably, we think) prefer to remove it by a moment's spot-grinding rather than attempt to prevent it by the routine use of a face-bow.

B. PROTRUSIVE RELATIONS

The kind of error introduced into protrusive occlusions, when casts are incorrectly related anteroposteriorly to the intercondylar axis, is shown in a general form in Fig. 4, from which it is apparent that the cusp angulation of

the molars which is necessary for balance in protrusion varies with their anteroposterior position. We are concerned to find the magnitude of the discrepancy produced when A is moved to A', a distance of 2 cm. We shall assume that the sagittal inclination of condylar and incisal guidances are 35 degrees and 5 degrees, respectively, these being commonly employed in practice, and that a protrusive excursion is made so as to bring the upper and lower molars from centric occlusion to a cusp-to-cusp relation.

If casts are mounted in the "average" position, it can be shown that the cusp inclination of the lower second molar necessary to achieve balance in protrusion is 18 degrees 10 minutes to the occlusal plane. In our patient, however, calculation shows that the required inclination is only 16 degrees 6½ minutes. In these circumstances, a protrusive relation in the mouth will cause a separation of the incisors because guidance at the molars is too steep. The maximum amount of grinding necessary to restore balance by reducing the cusp incline to 16 degrees 6½ minutes would be 0.107 mm. on one tooth, an amount comparable to a hair's breadth. The correction is shown graphically, though not to scale, in Fig. 5.

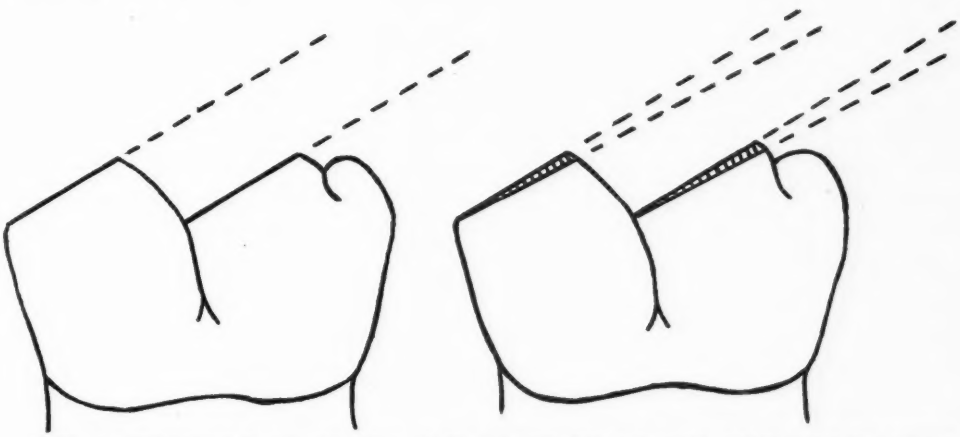

Fig. 5.—Exaggerated representation of the amount (shaded area) which must be ground from a lower molar in order to restore balance in protrusion when the anteroposterior position is changed.

Again the conclusion seems inescapable that the error introduced may be incapable of detection. It is certainly far smaller than the tolerance normally allowed in denture construction. Moreover, we have assumed a disparity of 30 degrees (35 minus 5) between condylar and incisal guidances. As these guidances approach identity at any magnitude, so do the errors of the kind shown approach zero. For example, if incisal and condylar guidances were both 30 degrees to the occlusal plane, the distance of the casts from the intercondylar line would have no influence whatever on occlusal relations in protrusion.

The reader who is mathematically inclined will notice at once that the example used to elucidate the problem is only one of many that might have been chosen. We might have considered the case in which casts are mounted too far forward (instead of too far back), or we could have discussed an instance in which incisal guidance was steeper than condylar guidance, and so on.

But the example chosen has the merit of representing a practical situation of common occurrence, and it illustrates reasonably well the order of magnitude of the discrepancies which would be produced in alternative arrangements of the variables. Again, in this section, and also in Sections A and C, a rather more precise and detailed geometrical analysis of the problems could have been attempted, but only at the cost of complicating an already difficult problem and without affecting the validity of the practical conclusions to be drawn.

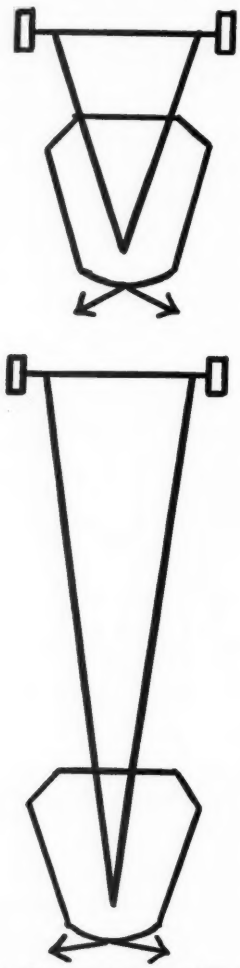

Fig. 6.—The general effect on the direction of lateral movements of changes in the anteroposterior position of casts.

C. LATERAL RELATIONS

Of the three primary movements (opening, protrusive, and lateral) made during mastication and reproduced by an articulator, the last is the most difficult to elucidate. To an even greater extent than in the two previous cases, we are obliged to simplify the exposition while yet retaining sufficient detail to ensure its validity for the particular purpose we have in mind.

Fig. 6 illustrates qualitatively and generally the way in which arcs along which the teeth move change their direction with an improbably large increase in the distance of the teeth from the point of lateral rotation on the intercondylar line. It will be apparent that if the casts were mounted at an infinite distance from the intercondylar line, lateral movements would then be parallel to this line, whereas in a normal mounting they take a distinctly forward direction.

To determine quantitatively the influence of anteroposterior positioning on the mutual relations of teeth in lateral occlusion, we shall make the same assumptions as before and we shall again consider the second molar because in this region errors will be maximal.

Imagine casts mounted in the "average" position and a mandibular movement to the right. The molar on the working side will move along an arc the tangent to which makes an angle of 23 degrees 27 minutes with the intercondylar axis or frontal plane. When the dentures are transferred to the mouth, the tangents will change their angulation slightly, that on the working side becoming 18 degrees 54 minutes. We now have to inquire what are the consequences of upper and lower molars gliding over each other in a direction which deviates 4 degrees 33 minutes from the intended direction. (This figure applies to the working side. On the balancing side, the deviation would be somewhat greater, but of the same order.) To give the error its greatest practical magnitude we shall assume that steep-cusped (30 degree) posterior teeth have been used and that the dimension of the cusp, from median sulcus to tip, is 3 mm. The exact analysis of the problem, which is that of movement of a point on an arc whose chord lies diagonally across an inclined plane, is complex; however, an approximate calculation indicates that the change in the opening component will certainly be less than 0.03 mm. Thus, correction of the discrepancy which arises in this instance through failure to use a face-bow requires that a maximum of 0.03 mm. be ground from a molar in order to restore balance in lateral occlusions.

EXPERIMENTAL CONFIRMATION

Since the results so far reported are derived from a mathematical analysis of the problem in its general form, they can be readily checked by other investigators using the same method. But for the sake of those readers who are unfamiliar with or distrustful of the mathematical techniques which must be employed, as well as for our own satisfaction, we have confirmed the calculated errors (in two of the cases considered above) quite simply by direct experiment.

Protrusive Relation.—To avoid the possibility of interference or unwanted guidance in the canine or premolar regions and to facilitate observations, the dentures used in the practical tests carried molars and incisors only. Although the centric occlusal relation of the dentures was unmistakable, additional rigidity was provided by removable plaster keys. Thus it was possible to detach the dentures and remount them in the same relative position irrespective of their absolute position in the articulator. The initial mounting in centric occlusion corresponded to a Bonwill triangle of 10 cm., and the occlusion was such that

upper and lower incisors and molars maintained contact in a protrusive relation. The intimacy of contact was checked with a 15/10,000 in. feeler gauge which could not be inserted between the upper and lower molar cusps from any angle of approach.

The dentures were returned to centric occlusion, locked in this relation with the plaster keys, and moved 2 cm. forward in the occlusal plane. This movement was facilitated by the parallelism of the arms of the articulator which rendered unnecessary a replastering operation. In this way, we simulated the placing of the dentures in the mouth of a patient having a Bonwill triangle of 12 cm. This change in position, of course, made no difference to molar or incisor contacts in centric occlusion, but when a protrusive movement of the same magnitude as before was made, the expected gap at the incisors developed, while the molars remained in contact. By direct measurement with feeler gauges, the gap at the incisors was found to be 8/1,000 in. To restore incisal contact, it was necessary to grind 0.0048 in. or 0.122 mm. from the molars. This practical determination compares well with the previously calculated value of 0.017 mm.

Opening Relation.—A similar procedure was followed. Because the experimental manipulation in this instance was more difficult, a wide variation was observed in the gap at the molars. The results of several attempts with feeler gauges lay between 10/1,000 and 20/1,000 in. The amount to be ground from the incisors to restore molar contact then lies within the range of 0.35 to 0.70 mm. It will be recalled that the calculated value was 0.5 mm.

CONCLUSION

In the three relations investigated, we have assumed a constant error of minus 2 cm. in fixing the anteroposterior position of casts in relation to the intercondylar axis. Similar results would have followed from calculation or direct measurement based on a positive error of the same amount. We believe that errors of this magnitude represent the maximum likely to be encountered in practice when, instead of making individual face-bow transfers, all casts are mounted at an average distance from the intercondylar axis. The resulting errors in the occlusal relations of full dentures are so small as to be incapable of clinical detection.

If, after more than fifty years of indecision, prosthetists decide to discard their face-bows, they may do so with a clear conscience. The time and energy thus saved can be expended in other ways with much greater benefit to the patient.

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NEURAL MECHANISMS OF COMMON SIGNIFICANCE IN CLINICAL MEDICINE AND PROSTHODONTIA

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THE TRITE aphorism, "Death enters through the mouth," was unchallenged in the pre-antibiotic era. The current trend in clinical medicine, however, is toward de-emphasis of focal infection[1] as the almost exclusive killer of mankind. Morbid anatomy has been largely superseded by functional pathology,[2] and, in practice, teaching, and research, the concepts of the mechanism of disease now envisage two components, damage and defense.[3] Whereas formerly the bacterial, neoplastic, or toxic pathogen[4] received almost exclusive attention, now there is a trend toward recognition of autonomic imbalance,[5] endocrine disturbances,[6] and nutritional deficiences[7] as important factors in disease. Since the buccopharyngeal area is the common seat of both functional as well as organic disease, we may well paraphrase the above-quoted aphorism to read: "Life worth living demands an adequate buccal portal."

Normal buccopharyngeal function requires an efficient, automatic and synchronized mechanism for the ingestion of food and the provision of an unobstructed airway. Valves and sphincters derived from vestigeal respiratory organs, the gill arch musculature of the lower aquatic vertebrates, separate food and air passages. Food and drink are prevented from regurgitating into the nose; air pressure is equalized within the pharyngotympanic tube and middle ear; a sphincteric "watchdog" guards the laryngeal introitus and protects the lungs; among several other functions, the sphincteric rima glottidis vibrates and phonates—a vocal exploitation of the most recently acquired phylogenetic transformation.

For the past four decades I have devoted much attention to medical and dental education, especially in the subjects of functional and clinical anatomy. During more than one-half of that time, while actively engaged in the practice of surgical oncology, many cases were seen in which a considerable portion of one or other of the organs of mastication, deglutition, and speech had to be sacrificed. Direct vision, through large buccal or other facial hiatuses, permitted observation of the marvelous compensating functional movements following hemiglossectomy, partial mandibulectomy, buccoalveolar resection for antral cancer; epiglottectomy in cancer at the vallecula; removal of the hyoid body during excision of thyroglossal duct cyst, and laryngofissure and excision of one vocal cord for low-grade intrinsic cancer of the larynx. Closure of buccal fistulas and

Read before the Academy of Denture Prosthetics, New Orleans, La., March 19, 1952. Received for publication March 19, 1952.

prosthetic devices or obturators provided by our dental conferees resulted in satisfactory long-term survivals (up to twenty years) in those of our patients whose lesions, although often locally extensive, were of low-grade type, amenable to radical surgical extirpation. Our experience in teamwork with prosthetic specialists has been a source of comfort and satisfaction. Successful practice as a peripheralist in some highly specialized local field does not, however, justify the overemphasis of technology at the expense of an effort to comprehend and apply the basic principles of biology.

In accordance with the therapeutic aphorism of *non nocere* ("not to hurt"), there is an ever-increasing trend among general and oral surgeons to envisage restoration of normal physiologic function and to utilize in every way the natural processes at hand. The phonation-deglutition technique is an example of the effectiveness of this principle. The biologic basis for the maneuver which determines the so-called "nonfunctional" rest position as the initial point for mastication, and therefore the physiologically correct point for registration, is fundamental, simple, and primordial. The same smooth, chainlike synchronization of movements that are characteristic of involuntary motor functions, such as peristalsis or ciliary action, may be envisaged through large buccal fistulas and have been strikingly well recorded by the cinéphotographic method. (Veterans Administration Dental Department Film, Chamblee, Ga.) The harmonious sequence of movement, beginning with the closure of the jaws and lips, followed by elevation of the tip of the tongue, and later by the powerful elevation of the base of the tongue, hyoid bone, and larynx, requires less than a second to perform. The first stage of deglutition is followed by propulsion of the bolus backward against the soft palate and epiglottis and then through the oropharyngeal isthmus and pyriform fossae through the pharynx, and into the esophagus. This, the second stage of deglutition, requires, according to Saunders and his associates,[8] only ⅓ of a second. By cinéradiographic methods, these observers have found definite visible evidence that apparently solves the movements of the hyoid bone, epiglottis, and aryepiglottic sphincter. The hyoid bone is not only elevated, but the body of the bone is rotated. The base of the epiglottis ascends with the hyoid bone as the result of tension upon the hyo-epiglottic ligament. The cephalic half of the epiglottis is rotated backward and downward to a maximum point at 60 degrees below the horizontal plane. The tip of the epiglottis is approximated against the constricting pharynx, except for the space occupied by the semisolid bolus. Between the base (cushion) of the epiglottis and the arytenoid cartilages, the aryepiglottic folds are markedly shortened, and the introitus of the larynx is thereby sealed. The constrictors of the pharynx contract from above downward, thereby aiding the downward projection of the bolus. Semisolid foods pass down upon the epiglottis, apparently aiding its descent; liquid pabulum traverses the pyriform fossae. These data show that the normal epiglottis does definitely descend and tends to cover the introitus like a trap door. It is also true, however, that after surgical excision of the epiglottis, the aryepiglottic sphincter is able to compensate and effectively guard the airway.

The remarkable celerity and automatic ease of normal mastication and deglutition indicates a functional mechanism that is based upon long-established automaticity. Clinical observation, now established by cinéradiographs, show that in about 2/30 of a second after deglutition the mandible (and other structures) return to the original rest status. Actually the rest position is not one of static loglike inactivity. It is a position of evenly balanced muscular tone, a dynamic but comfortable stability, which is the physiologic position for registration of optimal occlusion.

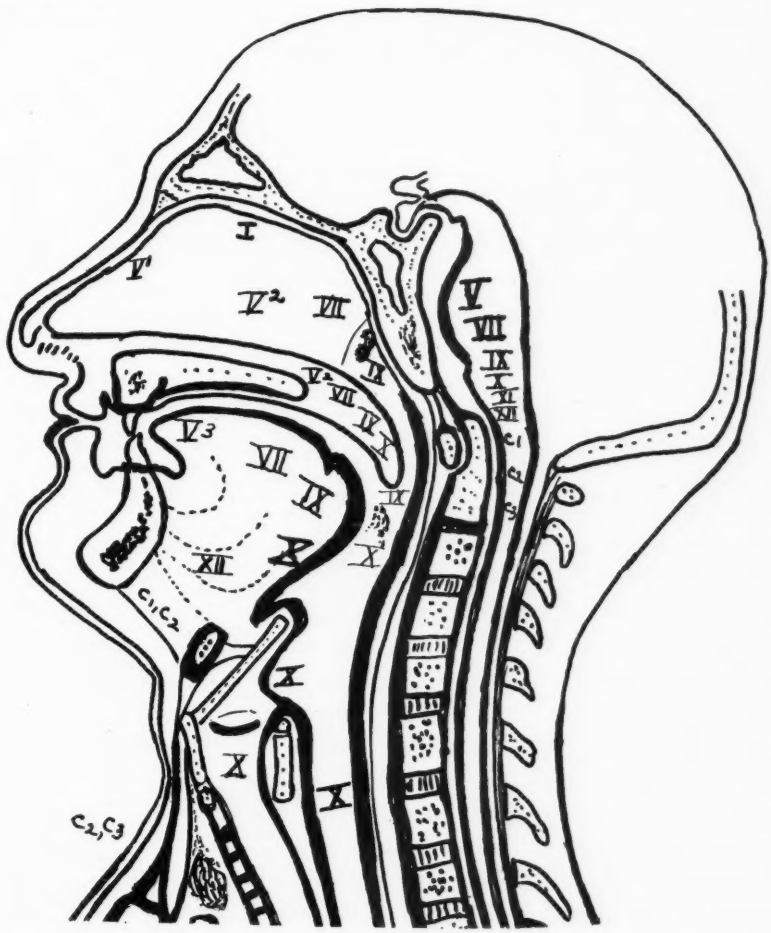

Fig. 1.—Hemisection of head and neck. Peripheral distribution and brain stem connections of cranial and cervical nerves involved in mastication and deglutition. Note cephalocaudal sequence in the branchiogenic nerves, namely, V, VII, IX, and X; also in the closely related and integrated XII, and upper cervical spinal nerves.

Natural phenomena are always deceptively simple. The illusion might exist that the movements of the thirty-odd pair of muscles, that act over three pair of joints in the combination of phonation with deglutition (Fig. 1), are so elementary that either all the answers are available or else unworthy of serious scientific research. If this were only partly true, the enigma of the temporomandibular

joint should have long since been solved. I can contribute to this phase of our subject only the following data upon the clinical anatomic aspects of these joints.

Unilateral excision of either the cricothyroid, the cricoarytenoid, or the temporomandibular joint, or severance of any one of the sensory or motor nerves that mediate the reflexes which control the functions of these joints, are all compensable lesions. Movements at these joints are performed by muscles that have evolved from the primordial musculature of the rostral four-gill arches of lower aquatic vertebrates. In cephalocaudal sequence, the musculature of each gill arch and its innervation may be listed as follows:

1. Masticatory musculature; first or mandibular branchial (gill) arch and mandibular division of the trigeminal nerve.
2. Labiofacial (buccinator) musculature; second or stylohyoid branchial arch and the facial nerve.
3. Palatoglossal and stylopharyngeal musculature; third or hypo-epiglottic branchial arch and the glossopharyngeal nerve.
4. Palatopharyngolaryngeal musculature; the fourth branchial arch and the pharyngeal and laryngeal branches of the vagus nerve.

In addition to gill arch musculature (Fig 2), which is supplied by special visceral efferent fibers in the trigeminal, facial, glossopharyngeal, and vagus nerves, important accessory functions in mastication, deglutition, and phonation are carried out by somatic musculature of the tongue, which is supplied by the hypoglossal nerve, and by the fixators of the hyoid bone which are also somatic muscles and are supplied by the ansa hypoglossi nerves.

Bilateral lesions of the organs of mastication, deglutition, and phonation are also compensated for in many cases. Deglutition and phonation are both recovered after complete laryngectomy. Bilateral meniscectomy or even complete arthrectomy of the temporomandibular joints may be successfully performed if careful technique is utilized to avoid damage to neuromuscular and neurovascular mechanisms.

These examples indicate the marvelous adaptive power of the human species in the "adjust or perish" preservation of vitally important automatic and autonomic functions. It is reminiscent of the environmental adjustments that have been made in organic evolution to changes in available pabulum, oxygen supply, and the requirements for specialized receptors of taste, smell, sight, audition, and balance. It is truly amazing how closely these organs function cooperatively in normal ingestion, and the compensations available when either of them are involved in functional or organic disease.

The scope of this paper does not include the various ingenious techniques for measuring the kinesiology of the temporomandibular joint by gnathodynamometry, nor visualization of its movements by the newer technique of cinéradiography. Only a few fundamental principles that apply to all joints, followed by a brief summary of the specific mechanisms in mastication and deglutition, can be given at this time.

Fig. 2—Primordial gill arch musculature and its definitive distribution.

A, Amphioxus. An agnathic branchiostome.

B, Elasmobranchii. Note the jaw musculature in the shark.

C, Human embryo at about 8 mm. stage. Primordial muscles and nerves at the cervicocephalic juncture.

D, Branchiogenic musculature of face, scalp, and neck.

E, Deglutitory musculature. Constrictors of the pharynx.

F, Temporalis, masseter, and buccinator muscles.

G, External pterygoid, internal pterygoid, and buccinator muscles.

All joints are primordially gliding and/or rotatory. The temporomandibular joints are capable of tridimensional function although they are primordial ginglymoid diarthroses. The tridimensional range of motion is required for an omniverous creature, such as man. The jaws have been evolved from the agnathic Amphioxus (Fig. 2), through the hinge-jointed carnivores, and the horizontally dentate herbivores wherein emphasis is given to the function of the pterygoids and lateral excursion of the molars. In the head of a newborn human being, the articular eminence is undeveloped.[9] It is not until late childhood that the deep articular fossa, similar to that of carnivores, is developed. While it is probably true that a hinge component is present in all movements of the temporomandibular joint, the inference that the carnivore type of motion is adequate for human dentition is not physiologically sound.

Normal kinesiology requires, in general, a conception of the neuromuscular action pattern for each type of movement at any given joint. Movements are controlled from the encephalon, where they may be initiated, but are always modified by reflexes that largely originate in the proprioceptors[10] of the locomotor structures (Fig. 3). Clinically significant proprioceptor nerves supply the joint capsule, periarticular tissues, and the muscles that pass over and move the joint. In this connection, Hilton's law of reciprocal innervation of the joint, the functional muscles that pass over the joint and the overlying skin of the joint region, is based upon embryogenetic factors that are especially applicable to the temporomandibular joint. Clinical implications are obvious.

The kinesiology of the temporomandibular joint in common with all other diarthroses requires conceptions of the differential structure of the musculature, the proximity and differential action of the various components of each muscle, and the combination of actions that are required to produce movements in each of its different planes. Although every muscle has more than one action at its joint, the brain is concerned primarily with functions. Only one of several potential actions may be required of each of several muscles to bring about the functional movement required. In any given movement, one of the actions of each of several muscles may be called upon to function as the prime mover (agonist or protagonist) of the motion required. At the same time similar actions are required to function as antagonist (actually reciprocally compensatory) whereas other muscles serve as synergists and fixators for important accessory functions in the movement. Not only is the type of movement governed from the brain, but also the power and celerity of that movement. At any one instant during a muscle movement these factors are dependent upon the algebraic sum of the power of contraction of all the muscles acting upon the joint. For those who are mathematic minded, reference is made to the volume on *Propedeutics in Orthopedic Diagnosis*.[11] Steindler and his associates have measured the force exerted by voluntary musculature. Muscles differ in the arrangement of their fibers, some being unipennate, others bipennate, still others multipennate. The functional cross section of a muscle is the same as the anatomic cross section in only one type, namely, the unipennate muscle. Despite other variables such as the amount of fibrous or elastic connective tissue content of muscle, the unit of

maximum voluntary muscle force was computed by Steindler and associates at 3.6 kg. per sq. cm. of physiologic cross section when the muscle is voluntarily contracted as forcefully as possible against a resistance that will not allow it to shorten. Muscle force progressively diminishes during shortening. The maximum amount of shortening possible in a voluntary muscle has been estimated at 57 per cent of its greatest length, or approximately 50 per cent of its relaxed length.[10]

"In a complicated mechanical system only a comprehensive picture of all component parts can lead to a true appreciation of the type and degree of any deficiency. Evaluation must be based on the kinetic performance of the whole mechanical system."[11] Fortunately, the prosthetist has not been required to employ higher mathematics and ultrascientific biophysics in order to satisfy the needs of the average edentulous patient. He knows that, even after the removal of both mandibular heads, adequate movements of mastication may be acquired. Since the masticatory muscles support the lower jaw as if in slings, and exert innumerable delicate and complicated movements that vary in different individuals, successful prosthodontia requires individualization of adjustment to shape, size, and movements of the patient. The converse is also true as any patient will confirm, but no good prosthetist would depend exclusively upon the capacity of the human body to make complete adjustment to any or all types of dentures.

Myogenetic imbalance[11] contractions from peripheral nerve lesions sometimes occur. Spastic contractions are much more frequent. They are due to a reflex overstimulation that follows local irritation with spasm (vasospasm) in the joint or in the musculature itself. Such myalgias are the common cause of "noninfected sore throats." They are due to ischemia of the pharyngeal constrictors which arises as part of the autonomic imbalance that is, in fact, an alarm reaction. The patient is the victim of a derangement of the general adaptative syndrome against nonspecific stress and strain. True myostitic contractures due to organic disease of the muscles of mastication and deglutition may occur, but they are rare. Desmogenic contractures, with infiltrations about the temporomandibular joint, occur in arthritis and other less common organic conditions. Costen's syndrome[12] may occur in either the spastic or the desmogenic type of contracture.

A few words must be said concerning the reflex mechanisms from the viewpoint of neural anatomy (Fig. 3). For some perhaps very good reason, the average graduate student exhibits a negativistic mental block to learning or relearning the nomenclature of the functional components of the cerebrospinal nerves. For those who are not completely allergic to unaccustomed terminology, an outline that we have found useful for our graduate students in Clinical Anatomy of the Head and Neck is included (Table I), together with tables of the components, ganglia, and nuclei of the cerebrospinal nerves (Tables II and III).

Suffice it to say here that there are three main pain pathways[13] from the region involved in the functions of mastication, deglutition, and phonation. One of these is somatic, and consists of exteroceptor and proprioceptor nerve fibers that course in the trigeminal, facial (Fig. 4), glossopharyngeal, and vagus nerves, synapse in the trigeminospinal nucleus and again in the thalamus, before reach-

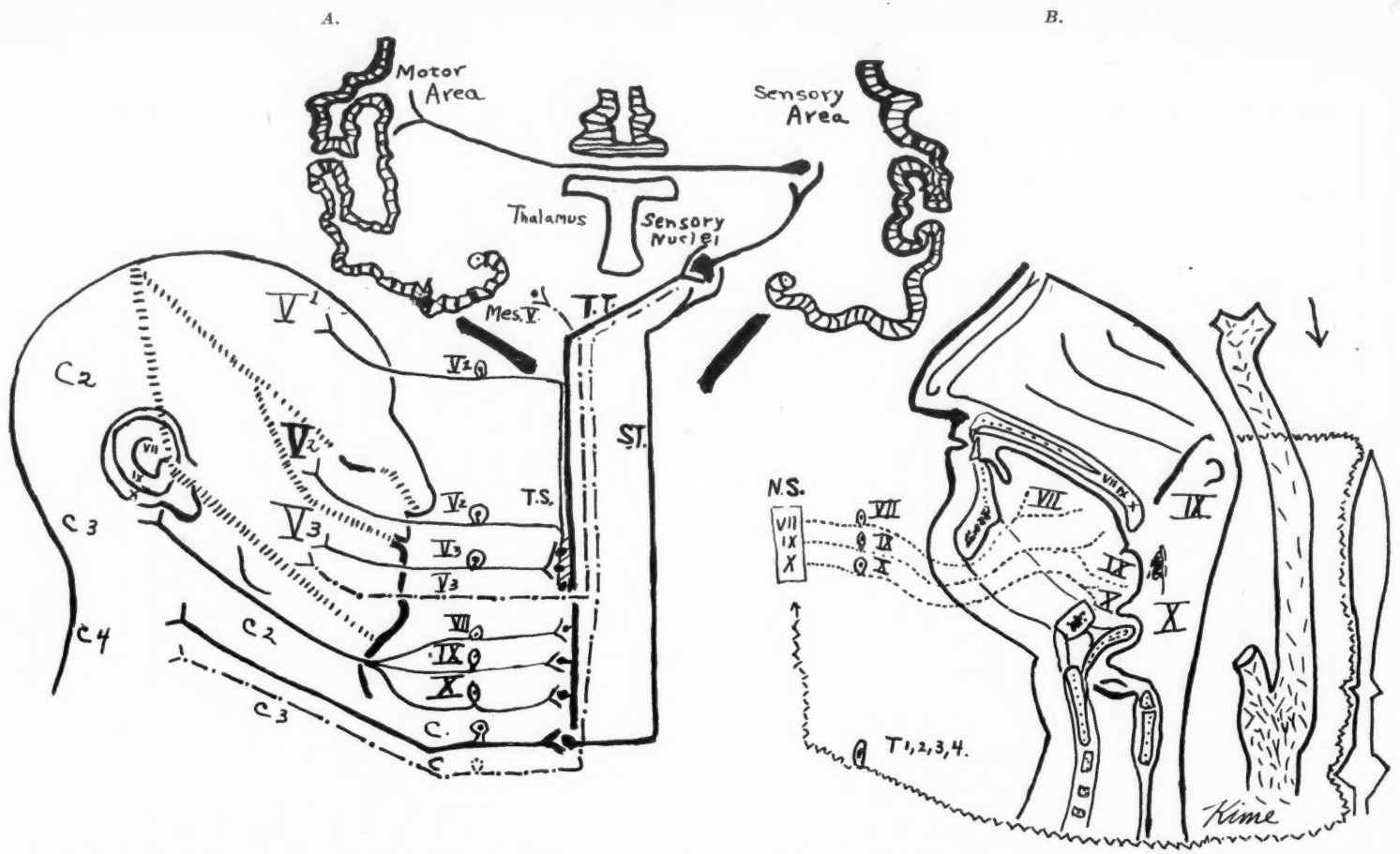

Fig. 3.—Somatic and visceral pain pathways of the head and neck. A schematic illustration of clinically significant afferent pathways that serve as the sensory limb of important reflexes in the control of mastication, deglutition, and phonation. The efferent pathways involve corticobulbar, corticospinal, and extrapyramidal projection tracts that are not shown in this illustration.

A, Somatic pain pathways.
————General somatic afferent—exteroceptive.
- - - General somatic afferent—proprioceptive.
T.S. Trigeminospinal tract.
T.T. Trigeminothalamic tract.
S.T. Spinothalamic tract.
Mes. V. Mesencephalic nucleus, V.

B, Visceral pain pathways.
. . . . . General visceral afferent. VII. IX. X.
~~~~~ General visceral afferent.
N.S. Nucleus solitarius.
Arrow (top right) indicates vascular pain pathway.
~~~~~

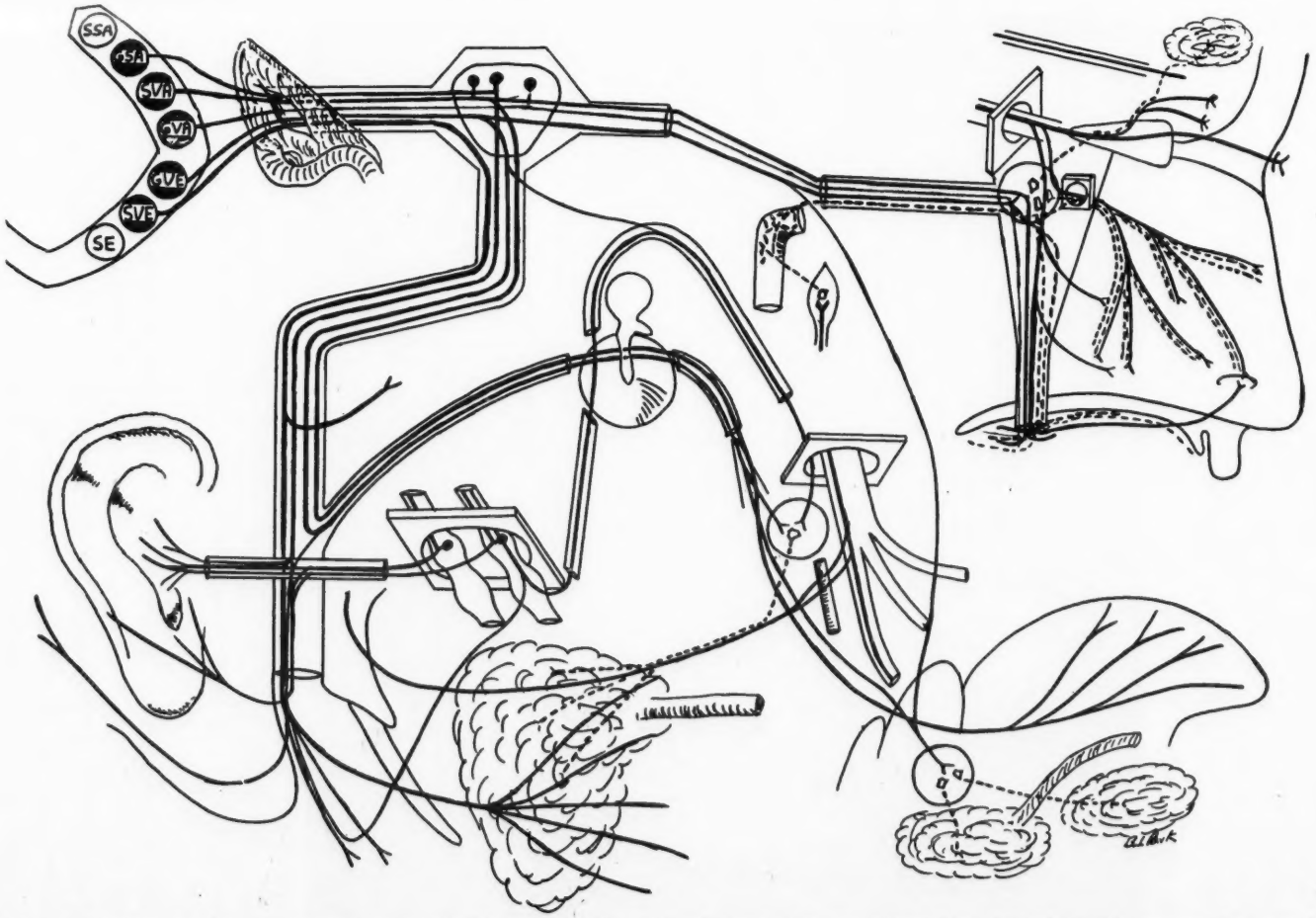

Fig. 4.—A diagram of the VII nerve, its functional components, and relations with the other three branchiogenic nerves that are involved in mastication, deglutition, and phonation (V, IX, and X). (B. J. Parks, artist.)

T.S. Trigeminospinal tract.
T.T. Trigeminothalamic tract.
S.T. Spinothalamic tract.
Mes. V. Mesencephalic nucleus, V.
N.S. Nucleus solitarius.
Arrow (top right) indicates vascular pain pathway.

in the pain-perceptive centers in the cerebral cortex. The other two pain pathways are viscerosensory. Although their upper neurone connections are not as yet completely known, they have been followed to the lower levels of the central nervous system. The visceral sensory fibers of taste, and general visceral-entroceptive pain pathway, follow the facial, glossopharyngeal, and vagus nerves to the nucleus solitarius in the medulla. The third pain pathway, most recently described,

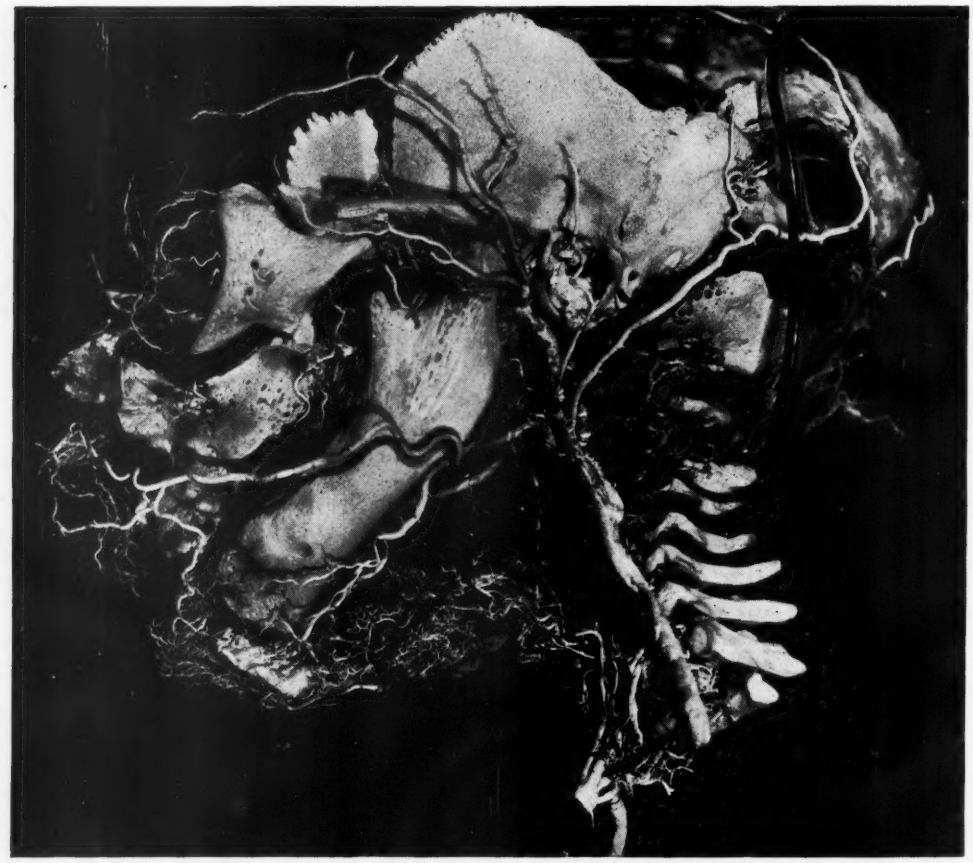

Fig. 5.—The blood vessels in the neonatal head and neck. (Vinyl acetate preparation. Department of Clinical Anatomy, Indiana University. [McAlpin].) Noteworthy is the vascular condensation at the craniocephalic juncture, and the demonstration of perivascular nerve plexuses.

consists of general visceral sensory fibers that accompany the periarterial plexuses of the arteries of the head and neck, mainly, the carotid vessels. This afferent pathway returns pain stimuli to the thoracic spinal cord via the sympathetic trunk and the upper four white rami communicantes.

Wolff[14] has clarified the clinical anatomy of the pain-sensitive structures within the head and neck. The arteries are important pain-sensitive structures (Fig. 5). This particularly applies to the branches of the external carotid artery that supply

the masticatory, deglutitory, and phonatory apparatus. Neuralgia, deep seated within the face, or involving the musculature, gingiva, or other dental-bearing structures, is not infrequently caused by a functional spasm in the vasa vasorum or vasa nervorum. The vasospasm is due to a derangement of the general adaptative syndrome. Pain results from the reaction against nonspecific emotional stress or strain with activation of the hypothalamus and hypophysis and consequent mediation of adrenergic effects in the blood vessels. Vasoconstriction, hemoconcentration, hypoglycemia, and decreased endothelial permeability constitute the primary alarm reaction. This is followed by a shift to the cholinergic phase in which the vasodilation results in tension upon the pain receptors in the perivascular plexuses. Concomitant edema and increased secretomotor activity are to be expected.

Specific stress factors, pathogens, bacteria, viruses, antibody-reagin R factors, neoplasms, and congenital lesions of various sorts may serve as trigger mechanisms to set off the neuralgic pain. Often, however, they are obscure. Not infrequently the congenital lesion consists of either a hyperplasia or an aplasia, along the line of embryonic concrescence between the basicranium and the superior surface of the pharynx and within the deep portion of the face. It is at this site, closely related to the pterygoid process, pharyngotympanic tube, and temporomandibular joint, that congenital legions are likely to occur. Elongated hypertrophied styloid processes[15] are a good example. They have been shown to be a frequent cause of deep-seated neuralgia. Excision with cure has been the customary result. The primordial gill arch nerves and the branchial arteries are the forerunners of potential pain-sensitive structures. Since they are developed in the critical area between the primordial cranium and the gill arch structures that later become the jaws, tongue, pharynx, and larynx, the trigeminal, facial, glossopharyngeal, and vagus nerves and the branches of the carotid arteries (Fig. 5) are potential target organs for nonspecific irritation and neuralgic pain. The neurovascular bundles which are formed by the numerous branches of the gill arch nerves and arteries constitute coaxial nutrient and sensorimotor cables that thread their way through bony canals often no larger than a wheat straw. Is it any wonder that not infrequently such patients become medical orphans, who, in the words of Moench[16] have been "analyzed, x-rayed, massaged, fitted with glasses, relieved of their tubinates and perhaps all of their teeth" and still continue to have pain? May it not be possible that some of these victims of tension complain for no apparent good reason at all about tender, ill-fitting, or sporadically painful dentures? Since this dysfunction in the general adaptation syndrome is pleomorphic and variable, may it not infrequently prove to be the unknown factor in some of the problem cases that are the mutual concern of both the medical advisor and the prosthetist?

TABLE I.

AN OUTLINE OF CLINICAL ANATOMY OF THE HEAD AND NECK

Neurocranium versus Viscerocranium in Cephalon, Cervix, and Gula
Somatic versus Visceral Organology in the Head and Neck
Phylogenetic: Embryogenetic and Functional Anatomy—Basic Factors in:
- Cervicocephalic adaptations of general motor and sensory mechanisms
- Cephalic evolution of special somatic sensory organs and neurones
- Cephalic evolution of special somatic motor organs and neurones
- Cephalic evolution of special visceral sensory organs and neurones
- Cephalic evolution of special visceral motor organs and neurones

General Rule as to Phylogenetic Antiquity of Organs and Neurones:
- Somatic organs and neurones have been evolved more recently than visceral organs and neurones
- Special organs and neurones are more recent than general organs and neurones

Alar or Sensory Lamina versus Basal Motor Lamina of Spinal Cord and Brain Stem
Relative Location of Neurones Within the Above Laminae
- Phylogenetically older neurones are nearer to the sulcus terminalis

CERVICOCEPHALIC ADAPTATIONS OF THE GENERAL VISCEROMOTOR MECHANISM

- The visceral organs, their functional units, involuntary muscle and glands, are of most ancient phylogeny
- The general visceral efferent fibers (abbreviated as G.V.E.) constitute the autonomic nervous system
- The autonomic pathway from cortex to hypothalamus
- The hypothalamic centers and pathway to lower autonomic centers
- The pathway from lower centers to effector is a two-neurone chain
- The location of the synapse in an autonomic ganglion. Acetycholine
- The relative position of the ganglia of the thoracolumbar versus the craniosacral nerves. The sympathetic versus parasympathetic nerves, the adrenergic versus the cholinergic nerves
- The adrenergic versus the cholinergic neurochemical mechanisms
- The sympathetic gangliated trunk and its cervicocephalic distribution
- The clinical significance of associated general visceral afferents
- The parasympathetic neurones course in III, VII, IX, and X (XI). Location of their nuclei
- The unique parasympathetic ganglia, namely, ciliary, sphenopalatine, submaxillary, and otic ganglia. The so-called "three roots" of each
- The typical terminal type parasympathetic ganglia for the vagus

CERVICOCEPHALIC ADAPTATIONS OF THE GENERAL VISCEROSENSORY MECHANISM

- The enteroceptors and the mechanism for reception and conduction of visceral sensation are phylogenetically ancient in origin. The visceromotor reflex
- The general viscerosensory pathways:
  - That accompany the sympathetic nerves, via sympathetic trunk and white rami communicantes. Function mostly for pain sense
  - That accompany the parasympathetic nerves
- Deep sensibility and tone factors concerned with filling and emptying of the viscera
- The general visceral afferents (G.V.A.), that serve as functional components of the VII, IX, and X nerves, have their cell bodies in the geniculate, petrous, and nodose ganglia and terminate in the nucleus solitarius

TABLE I—Cont'd

CERVICOCEPHALIC ADAPTATIONS OF THE GENERAL SOMATIC MOTOR MECHANISM
The oculomotor muscles. III, IV, and VI
The glossal musculature. XII
The infrahyoid muscles, ansa hypoglossi—C 1, 2, and 3
The prevertebral muscles, and related muscles located immediately behind the prevertebral fascia, anterior primary rami of cervical nerves
The "native muscles of the back"—posterior rami of cervical nerves
The diaphragm. C 3, 4, and 5. A special somatic motor mechanism?
The cervical plexus and the brachial plexus. Distribution of each
The single chain neurone from C.N.S. to effector is called G.S.E.
Somatic musculature is comparatively recent in phylogeny
CERVICOCEPHALIC ADAPTATIONS OF THE GENERAL SOMESTHETIC MECHANISM (SEE FIG. 3)
Mediation of pain, touch, and temperature by exteroceptor fibers—G.S.A.
From the external envelopes of the body—dermatome derivation
Mediation of postural sensation, etc. Proprioceptors
From muscles and muscle tendons—myotome derivation
From bone and joints—sclerotome derivation
Segmental somatic sensory innervation through:
The trigeminal nerve. V-1 (ophthalmic nerve) and the frontonasal process. V-2 (maxillary nerve) and the maxillary process. V-3 (mandibular nerve) and the mandibular process. Significance of the "chin-ear-vertex line"
The gasserian ganglion. The three sensory nuclei of the V cranial nerve. The VII, IX, and X. Lateral line vestiges. Geniculate, superior, and jugular ganglia
The trigeminospinal nucleus. The upper four cervical nerves, anterior and posterior rami C 1 sensory in approximately 10 per cent of cases
Cephalalgia and cervicocephalic neuralgia
Surgical interventions for the control of intractable pain
Neurectomy
Ganglionectomy
Sympathectomy
Rhizotomy
Tractotomy
Leukotomy
CEPHALIC EVOLUTION OF SPECIAL SOMATIC SENSORY ORGANS AND NEURONES
The organs of smell, sight, and hearing of recent phylogenetic development
Placode embryogenesis. From surface ectoderm
Special somatic afferent neurones (S.S.A.). In I, II, and VIII
Location of the cell bodies of the primary sensory neurone
Location of the cell bodies of the secondary and tertiary neurones
Location of the cortical and subcortical centers
CEPHALIC EVOLUTION OF SPECIAL SOMATIC MOTOR ORGANS AND NEURONES
The respiratory diaphragm, a highly specialized muscle of somatic origin but of visceral function, is suggested as representative of this class. The motor fibers of the phrenic nerve from C 3, 4, and 5 would then be classified as special somatic motor neurones. S.S.E. See comment below for comparable situation with reference to special visceral efferent nerve.

TABLE I—Cont'd

CEPHALIC EVOLUTION OF SPECIAL VISCERAL AFFERENT ORGANS AND NEURONES

Neurochemical taste mechanism related functionally with smell, and taste bud embryogenesis from endoderm of upper three branchial pouches

Special visceral afferent neurones. VII, IX, and X. Ganglia—geniculate, petrous, and nodose. Brain stem termination in the nucleus solitarius

CEPHALIC EVOLUTION OF THE SPECIAL VISCERAL MOTOR ORGANS AND NEURONES (SEE FIG. 2)

Primordial branchial or gill arch musculature—intermediate in phylogeny between involuntary muscle and somatic skeletal muscle

Embryogenesis of branchial musculature is not somatic, but from the uncleft head mesenchyme of the respective branchial arches

Appearance of branchial arches chronologically:

Mandibular or first arch. Masticatory and four other muscles

Stylohyoid or second arch. Stapedius plus numerous mimic muscles. Innervation by the main motor or S.V.E. fibers of VII

Hyoid arch or third arch. Stylopharyngeus muscle. Innervation by the S.V.E. Component of IX

Laryngopharyngeal arch. Muscles of pharynx, soft palate, and larynx. Innervation by the S.V.E. Component of X (XI?)

Lower arches—not distinct in human being. Sternomastoid—trapezius. Innervation by the S.V.E. Spinal component of XI

Special visceral efferent neurones (S.V.E.). Although termed visceral, these nerves are single-chain neurones from motor nuclei of V and VII, and from the nucleus ambiguous to the effector in the striated muscle that has evolved from a former visceral-functioning, gill opening and closing mass of muscle. Since the musculature was originally visceral, the neurones that supply it are classified as special visceral efferents. Neither the musculature nor the supplying neurones would be correctly designated as "somatic."

SUMMARY OF SOMATIC VERSUS VISCERAL NEURONES, MEDIATED VIA THE CRANIAL NERVES AND BY THE PHRENIC NERVE

S.S.A.	I, II, and VIII. Alar lamina. Most recent phylogeny
G.S.A.	V, VII, IX, and X. Alar lamina. Recent phylogeny
S.V.A.	VII, IX, and X. Alar lamina. Less recent phylogeny
G.V.A.	VII, IX, and X. Alar lamina. Ancient phylogeny
G.V.E.	III, VII, IX, and X (XI). Basal lamina. Ancient phylogeny
S.V.E.	V, VII, IX, X and XI. Basal lamina. Less ancient phylogeny
(G)S.E.	III, IV, VI, and XII. Basal lamina. Recent phylogeny
S.S.E.	C 3, 4, and 5. Basal lamina. Most recent phylogeny. Special somatic efferent (a term suggested by the author) to complete the series of functional components and consistent with the unique visceral function of the diaphragm, a muscular organ of somatic origin

CLINICAL AND APPLIED ANATOMY OF THE FOLLOWING REGIONS AND CONDITIONS

Face, scalp, orbit and intracranial fossae

Lacrimal and salivary glands

Cheek, nose, and palate

Pharyngotympanic tube, tympanum, and epipharynx

Alveolar processes, gingivae, and teeth

Lower jaw, tongue, and floor of the mouth. Submandibular region

Faucial tonsil, pterygoid region, and hypopharynx

Suprahyoid region, larynx, and laryngopharynx

Infrahyoid region, trachea, esophagus, and carotid sheaths. Lymphatics and thyroid

Parathyroid, thymus, ultimobranchial, thyroglossal, and branchial cysts

The cervical fascia; infections in the neck. Root of the neck

Neoplasms and cysts in the head and neck

Wounds and other trauma to the head and neck

TABLE II. COMPONENTS, GANGLIA, AND NUCLEI OF SPINAL VERSUS CRANIAL NERVES

SPINAL NERVES				CRANIAL NERVES			
COMPONENTS	NUMBER	GANGLIA	NUCLEI	NO.	GANGLIA	NUCLEI	LOCATION
G.S.A. exteroceptors Proprioceptors Lat. line receptors	All 31 pairs	Dorsal root	Posterior horn of spinal cord Thalamus	V_1 V_2 V_3 VII IX X	Trigeminal Semilunar- Gasserian Geniculate Superior Jugular	Mesencephalic Main V Desc. spinal Nucleus V	Midbrain Pons Medulla and upper spinal cord
G.V.A.	T1–12 S2–S4 (All 31 pairs)	Dorsal root Ganglia of T1–12 & S2–S4 via W.R.C. (G.R.C. ?)	Posterior horn of spinal cord Thalamus	VII IX X	Geniculate Petrous Nodose	Nucleus Solitarius	Medulla
G.V.E. Thoracolumbar Craniosacral	All 31 pairs Distal to G.R.C. T1–12	Sy. trunk or Prevert. Sy. GG. Terminal	Lateral horn of spinal cord	III VII IX X	Ciliary Sphenopalatine Otic Terminal	Edinger-Westphall Superior Saliv. Inf. saliv. Dors. Mot. X, (XI)	Midbrain Pons Medulla Medulla
(G) S.E.	All 31 pairs	None	Ventral horn of spinal cord	III IV VI XII	None None None None	Oculomotor Trochlear Abducens Hypoglossal	Midbrain Midbrain Pons Medulla
S.S.A.	None	None	None	I II VIII	Olfactory mucosa Retina Int. ear	Mitral cells Sup. Col., Lat. Gen. Inf. Col., Med. Gen.	Olfactory lobe Midbrain Midbrain
S.V.A. (taste)	None	None	None	VII IX X	Geniculate Petrous Nodose	Nucleus Solitarius	Medulla
S.V.E. (branchial)	None	None	None	V VII IX, X XI	None None None None	Mot. of V Mot. of VII Ambiguous Ambiguous	Pons Pons Medulla Medulla
S.S.E.*	3, 4, and 5	None	Ventral horn of spinal cord Seg. 3, 4, and 5		None	None	None

*Special somatic efferent. This terminology is suggested as applicable to the efferent component of muscular nerves to somatic musculature that subserves a visceral function, for example, phrenic.

TABLE III

CLASSIFICATION	SMELL	TASTE	SIGHT	BAL.	ACOUSTIC	NO. OF CRANIAL NERVES
Mammals	+	+	+	+	+	12
Aves	+	+	++	++	+	12
Reptilia	+	+	+	+	+	12
Amphibia (Frog)	+	+	+	+	+	10
Fishes	+	+	+	Lat. line	?	10
Cyclostome	+	+	+	Lat. line	–	10
Acrania	+	+	–	–	–	2

CRANIAL NERVES AND THEIR COMPONENTS

NAME	NO.	S.S.A.	G.S.A.	S.V.A.	G.V.A.	G.V.E.	S.V.E.	S.E.
O.	I	+	–	–	–	–	–	–
O.	II	+	–	–	–	–	–	–
O.	III	–	+P	–	–	+	–	+
T.	IV	–	+P	–	–	–	–	+
T.	V	–	+E +P	–	–	–	+	–
A.	VI	–	+P	–	–	–	–	+
F.	VII	–	+E +P	+	+	+	+	–
A.	VIII	+	–	–	–	–	–	–
G.	IX	–	+E +P	+	+	+	+	–
P.	X	–	+E +P	+	+	+	+	–
S.	XI	–	+P	–	–	?	+	–
H.	XII	–	+P	–	–	–	–	+

P indicates proprioceptors.
E indicates exteroceptors.

SUMMARY

1. The neural mechanisms of common interest in clinical medicine and prosthodontia involve chiefly the functions of mastication, deglutition, and phonation.

2. The sensory components of the reflex arc are somatic exteroceptors and proprioceptors that course mainly in the trigeminal nerve but may also

course in the somatic branches of the seventh, ninth, and tenth cranial nerves—the so-called "vestigeal lateral line" nerves. All somatic exteroceptors terminate in the trigeminospinal nucleus. The proprioceptors of the masticator muscles terminate in the mesencephalic nucleus of the trigeminal nerve.

3. Visceral sensory impulses for taste and general sensation course within the seventh, ninth, and tenth cranial nerves and terminate in the nucleus solitarius.

4. A clinically important pain pathway follows the perivascular nerve plexuses of the arteries and the sympathetic trunk. It connects with the spinal cord by way of the white rami communicantes of the upper four thoracic nerves.

5. Reflex stations between the sensory and motor limbs of the reflex arc are located at the lower spinal cord or brain stem levels, at the thalamus, and at the cortex.

6. Efferent pathways pass from the brain stem through the special visceral motor fibers of the primordial gill arch nerves, trigeminal, facial, glossopharyngeal, and vagus nerves and by the hypoglossal and upper cervical spinal nerves. The effectors are motor end plates that are distributed through the gill arch and functionally related somatic musculature. The muscles of mastication, the facial musculature, and the musculature of the soft palate, pharynx, and larynx are all gill arch muscles. Closely related somatic musculature is that which moves the tongue and fixes the hyoid bone.

7. The biologic basis for the phonation-deglutition technique of determining the rest position prior to registration has been considered from the phylogenetic. ontogenetic, and clinical anatomic viewpoint.

8. The functional pathology of motor and vasomotor imbalance within the organs of mastication, deglutition and phonation was considered from the viewpoint of compensatory mechanisms and with special reference to the general adaptation syndrome.

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A COMPARATIVE STUDY OF POSTERIOR OCCLUSION

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FIFTY years ago there was very little difficulty in selecting teeth for a denture patient, simply because there was very little choice. Contrast those days with the present when we are besieged with advertising in superlatives, with tooth carvings by the score, and the ingredients from which teeth are made constantly undergoing change in manufacturing techniques.

Dentists have learned from bitter experience that all products do not live up to what is claimed for them, and they rightfully have become wary.

The problem of choosing the best teeth for a denture patient today is likely to be very perplexing. There are men who feel that cusp posterior teeth are still the best, because this type imitates nature, or look better, or because the dentists are hesitant to change to one of the mechanical forms. The advocates of flat teeth claim that cusp teeth, by their inclines, cause movement of the denture bases and more resorption of the ridge than is necessary. Who is right?

To satisfy a personal curiosity, I have made a study of contrasting posterior tooth forms in the matters of efficiency and comfort, for the past two and one-half years. A preliminary article[1] appeared in the JOURNAL OF PROSTHETIC DENTISTRY. Briefly, the technique is as follows: Duplicate dentures are built for a patient. The same mold of anterior teeth is used and set as nearly identical as possible. Posterior 33 degree cusp teeth are used in one set, and one of the mechanical tooth forms is used in the other. The occlusal planes are made as nearly the same height as possible.

To do this, impressions and Korogel molds are made. Duplicate casts can then be made, and baseplates will be interchangeable. A tactile centric relation record is made, and the casts are mounted on the Hanau articulator with the face-bow. An intraoral tracer is used to obtain the final centric relation at the proper vertical dimension. A plaster check bite is taken, with the mandible in protrusion, to set the condylar inclinations. Both sets of casts are mounted and must be interchangeable.

The anterior teeth are set by checking one upper set against the other lower, and vice versa, until they are the same. Then the posterior teeth are set up according to generally accepted practices.

The patient wears one set for two weeks, then the other set for two weeks, and finally uses both sets at the same meal, making notes on their performance.

Here are the exact remarks of one patient wearing steel insert teeth versus 33 degree teeth:

Read before the Academy of Denture Prosthetics, New Orleans, La., March 17, 1952.
Received for publication March 17, 1952.

"Of the many kinds of food that I've eaten with both the regular set of teeth and the steel blade set, I find that many seem to be about the same. Such would be soft or boiled foods as potatoes, cabbage, peas, carrots, et cetera. The greatest contrast seemed to me to be in such foods as I would class as 'crunchy' as celery, lettuce, peanuts; and meats which I would call 'stringy,' such as steak, chicken, roast beef, pork, et cetera. My opinion is that the 'steel set' is superior for mastication when it comes to these foods."

Next, the patient is put through chewing tests to see if the actual results correspond with his subjective experience.

Sliced carrots, pressed ham, and blanched peanuts make up the standard test menu. Each patient chewed each food until the swallowing action occurred. The total number of chewing strokes was halved and the chewing repeated. The partly chewed food was deposited on a plate for examination. The tests were again repeated, but the chewing was stopped just five strokes short of the swallowing action, and the more finely divided food saved for examination.

Varied age groups and ridge types were chosen and the differences in performance were startling.

Patient No. 1 was a white girl, age 15 years, in good health with teeth lost from caries. The posterior teeth tested were Myerson Tru-Kusp vs. Trubyte 33 degree. Chewing strokes to swallow: pressed ham 2 x 2″ square, 9 strokes; carrots, 3 slices, 20 strokes; peanuts, 5 whole, 15 strokes. Results at about the half-way mark showed that cusp teeth had broken the food into much smaller particles.*

Patient No. 2 was a white woman, age 60 years, who was diabetic and had lost teeth from pyorrhea. Posterior teeth tested were French's vs. Trubyte 33 degree. Chewing strokes to swallow: pressed ham, 2 x 2″ square, 75 strokes; carrots, 3 slices, could not even go through; peanuts, 5 whole, 70 strokes.

Results showed that both sets chewed about equally, with a slight edge for the anatomic teeth. This patient had the poorest performance of any in her ability to force the teeth through tough food. Her ridges were also poor and the interridge space was large.

Patient No. 3 was a white man, age about 55 years, who was in good health. Posterior teeth tested were Hardy steel insert teeth vs. Trubyte 33 degree, Chewing strokes to swallow: pressed ham, 2 x 2″ square, 70 strokes; carrots, 3 slices, 65 strokes; peanuts, 5 whole, 70 strokes.

Results showed cusp teeth to be better on the initial breakdown. On chewing almost to the swallowing point, the cusp teeth were very slightly better on the

*The chewing tests described in this article were made by careful visual examination of the consistency, particle size, and uniformity of particle size of the food, both at the half-way point and at the swallowing threshold.

The use of mesh screen for testing tooth efficiency is scientific enough for the food which passes through the mesh, but does not take into consideration that which is left behind.

In exaluating the tooth form it is possible to statistically state that one may be 50 per cent more efficient than another, whereas such a difference does not exist from a practical standpoint. A patient, for example, who concentrates on chewing two peanuts out of a group of five, will have a good breakdown on the two and have a fairly good rating by screen testing, whereas three practically whole peanuts would be left behind.

The author feels that, from a digestive viewpoint, uniformity of particle size throughout the entire bolus is more important.

peanuts, about the same on the carrots, but not as good on the meat. This was actual performance, even though the patient felt that the steel insert teeth were much superior, as mentioned in the report given previously in this discussion.

Patient No. 4 was a white man, age 76 years, who apparently was in good health. Teeth tested were French's posterior vs. Trubyte 33 degree. Chewing strokes to swallow: pressed ham 2 x 2″ square, 35 strokes; carrots, 3 slices, 55 strokes; peanuts, 5 whole, 36 strokes.

At the half-way point, the cusp teeth were better on carrots, slightly better on meat, and quite a bit better on peanuts. At the terminal chewing, carrots were nearly the same, meat almost the same, but the cusp teeth still did better on the peanuts.

Patient No. 5 was a white woman, age about 40 years, who apparently was in good health. Posterior teeth tested were LaDue and Saffir Geometric vs. Trubyte 33 degree. Chewing strokes to swallow: pressed ham, 2 x 2″ square, 25 strokes; carrots, 3 slices, 43 strokes; peanuts, 5 whole, 38 strokes.

Results showed cusp teeth were better at half-way mark, but in the terminal chewing the flat teeth were better on carrots and peanuts. Meat seemed about the same.

Now, what are the facts? In the matter of efficiency, the performances of the teeth were fairly similar except with Patient No. 1 who did much better with the cusp teeth. For all practical masticating purposes, it wouldn't have made much difference which kind of teeth were used. The advantage gained on initial breakdown of the food by the cusp teeth seems to be somewhat offset later by the flat teeth. It is interesting to note that all of these patients felt that the cusp teeth were better for chewing than the flat teeth, with one exception—the steel insert teeth were considered to be superior. This would certainly show that the sensation of "feeling the teeth go through food" makes the patient believe that they are more efficient over-all. The steel blades, like the cusps, penetrate with less initial resistance and give rise to this conclusion.

Another interesting fact came to light. Patients chewed very nearly the same number of strokes with some foods with either set of dentures without knowing what the count was. For example, Patient No. 5, with the cusp teeth, took 43 chews to swallow the carrots, 25 for the meat, and 38 with the peanuts. With the flat teeth, she chewed for the same foods, respectively, 40, 23, and 36 times. There seems to be a sense of muscle timing for a certain sensory evaluation of the kind of food. Whether or not this is a neuromuscular habit set up from continued experience with natural teeth, and continued on with dentures, would be hard to say. Our actions and reactions in driving an automobile become automatic, and we do not have to think about applying the brakes when someone steps in front of the car. The reflex is automatic. Our behavior in chewing food seems to be similar. We take a bite, evaluate the size of the bolus, our muscles set themselves for the consistency, and we attack the food while the saliva pours out to keep things lubricated.

If eating were the only use for dentures, our job would be much easier, but this is only the beginning. Shanahan[2] separates denture function into masticat-

ing movements and nonmasticating movements. With these duplicate denture wearers, tracings were made of the chewing cycles which are the masticating movements, and also of the lateral free movements and lateral movements while maintaining tooth contact. These are, of course, nonmasticating in nature.

In these chewing cycles, the mandible moved downward on the opening movement, then proceeded laterally following a smooth curve, and then came from lateral up into centric. Looking at the patient from the side, the mandible moved downward and slightly backward, so the tracings could be recorded on a straight sheet of paper. As the bolus grew smaller the chewing strokes also shortened from the bottom upward. With the cusp teeth, the strokes came sharply into centric position; in the 15-year-old girl, the same point was reached with the flat teeth. In the teeth tested in the older people, the strokes closing into centric position were not as precise with the flat teeth. With the steel insert teeth, to my surprise, the patient opened, then closed toward centric position, and then moved straight into lateral. This produced a plateau effect across the top of the tracing. This occurred with all of the foods. That patient did not chew this way with the cusp teeth, but followed the conventional cycle. He could also chew in these conventional cycles with the steel teeth when he was asked to do so. He felt more efficient with the sliding movement. In obtaining tracings from another man wearing the steel insert teeth, the top of the chewing cycle had a broadly rounded top which the patient knew was a slide instead of a chop. (Fig. 1.)

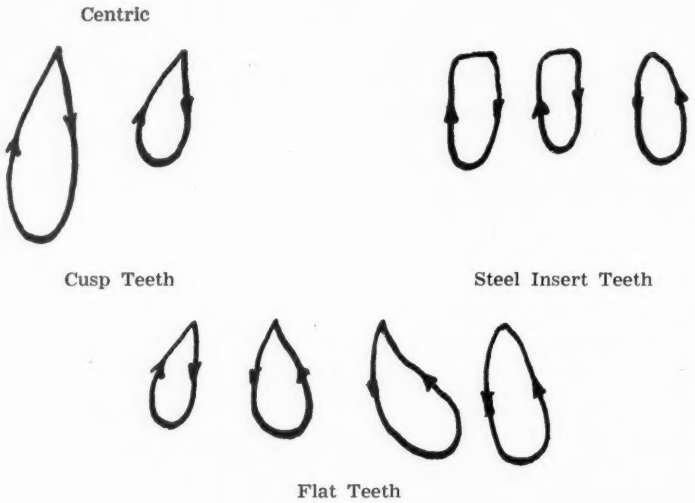

Fig. 1.—Some typical chewing cycles.

It seems clear that an individual will adapt to the method of chewing which he feels is accomplishing the best results in the breakdown of food. If the patient is a "chopper" with his natural teeth, he will probably start as a chopper with dentures and then if he has the ability to move into lateral position, change to a "shear" or a "glide" if he can do so with better results.

In the nonmasticating category of denture movements, the lateral free movement of the mandible describes an upward arc, which changes to a horizontal line in the working range of flat occlusal surfaces and into an inverted V with cusp teeth. Without exception, all the patients preferred wearing the dentures with the flat tooth forms even though each recognized that the cusp teeth were slightly more efficient. The man wearing the steel insert teeth, on the other hand, felt that these were more efficient.

This could lead to some interesting speculations and indicates to me that, while eating is a very pleasant pastime, the extracurricular activities of dentures are of extreme importance. People do bite and slide on their teeth, and the friction of the surfaces and inclines of the cusps produce movement of the bases on the tissue. Perhaps the easier this gliding can be done, the less disturbing it is to mouth comfort. I believe that wear facets are produced more quickly on teeth from bruxism than by chewing done at mealtime. If someone could build duplicate dentures and use one set only at meals and the other set the rest of the time, we could gain more valid information. Only a dentist or a patient under constant supervision could be used to make sure the right set was used at the right time. An institution might be the logical place to carry out such an experiment.

Can any definite conclusions and practical applications be made from what has been done? Certainly the fact that all patients who had had the dentures for some time preferred to wear the ones with flat teeth is a puzzling one. Each one felt that the cusp teeth were more efficient, except the patient with the steel insert teeth. This should not be interpreted to mean that everyone would prefer nonanatomic forms but *these* people did, and they felt more comfortable with them. In the masticating movements, a relatively narrow range of articulation is used, and the occlusal surfaces are padded with food while chewing. It would be logical to me to believe that the function of dentures between meals in the nonmasticating movements is extremely important. Here we have bare tooth surfaces grinding on one another with friction, as well as cusp inclines if they are present. As shown in the preliminary article,[1] the free movements of the mandible follow an upward arc while it moves in an inverted V following cusp inclines. This would certainly indicate that the introduction of cusp heights will increase thrust on the denture bases in lateral grinding movements with nothing between the teeth. With the tension and stress of modern life, this could be a very significant factor in ridge resorption. The thin, high-strung nervous patient is usually one of our most difficult problems and chronic ridge soreness is a common symptom. Improvement of nutritional and other systemic disorders plus a noninterfering type of articulation is helpful.

We can say definitely that the patient's evaluation of his efficiency with dentures is to some degree psychologic, based on actual performance versus his opinions. If a patient with normal tissues says he cannot chew well with a good set of dentures, the chances are that he is doing a better job than he thinks. Reducing the occlusal contact area and grinding escapeways will probably make him feel that he is penetrating his food better.

An adequate supply of saliva is an important factor in efficiency of teeth, in that it lubricates the bolus of food and facilitates its manipulation and positioning on the food table by the tongue and buccinator muscles.

We see that in actual chewing only a small range of movement is used in the actual occlusal contact area. The patient with the steel insert teeth varied the most, and used more width in the actual contact area. An accurate centric registration at the proper vertical dimension is of paramount importance for masticating stability with cusp teeth. However, it is in the nonmasticating activities of dentures that the refinement of articulation is of increasing importance for comfort and reduction of undue thrust, regardless of the type of posterior teeth used. Certainly, an adjustable articulator with the proper settings will aid in its attainment.

The patients in these tests showed that most of the flat teeth do a pretty good job of chewing, and these patients preferred them. They were a little less efficient, however. Where, then, shall we use cusp teeth or flat teeth? From a mechanical approach, it seems logical to me that where the ridges are quite flat, the bases will slide more easily than on the prominent, well-shaped ones. Also if the interridge distance is great at the selected vertical dimension, the increased leverage on the bases will cause them to tip more easily. In my opinion, flat teeth can be used to definite advantage in these situations, since there will be a maximum of vertical force and a minimum of horizontal force. Therefore, the greater the interridge space and the flatter the ridges, the more indication for flat posterior teeth. On the other hand, mouths with well-shaped ridges can take advantage of cusp teeth for increased penetrating ability and psychologic effect, without producing as much denture skid. A smooth articulation is important, and anteroposterior intercusping should be freed or eliminated to allow for some degree of settling.

The steel insert teeth, it seems to me, have a definite place in our choice. People with very heavy bites who break porcelain or wear resin teeth rapidly do very well with them. They can be used elsewhere, of course, but are of particular advantage in these cases.

We should select posterior teeth as we select impression materials. By evaluating the requirements and mouth conditions in each individual case, we can learn to utilize many forms of teeth to good advantage. All of the teeth that were tested performed well, and I believe we should make wider use of their possibilities.

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DISCUSSION

A Comparative Study of Posterior Occlusion, by S. Howard Payne, D.D.S.

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DR. Payne's paper is a timely one in view of the constantly recurring controversy on cusp versus cuspless posterior teeth.

It is a difficult and baffling subject because case conditions and techniques vary so greatly that it seems impossible to isolate unknown factors sufficiently to prove anything conclusively.

Our essayist has presented a report of a limited number of cases with dentures constructed under conditions for the two types of posterior teeth used for each patient that are probably as identical as is possible in practice. He made careful observations and drew conservative conclusions that seem indisputable within the limits of the conditions of his experiments.

It is true that a critic might say, for instance, that "One swallow never makes a summer" and, similarly, that one set of dentures does not constitute conclusive proof regarding any particular type of posterior tooth used in the project.

The paper clearly shows that the author agrees with this reasoning, and my offhand opinion is that the Fellows of the Academy will also agree. It must be remembered, however, that one man cannot do everything, and our essayist made no claim that he exhausted the subject.

It is also true that these conclusions are not new. Our Fellows have been using most, if not all, of this information for some time, and a number of interesting statements will probably follow this introductory discussion. This is certainly not a criticism, however, because the paper made no claim to originality; it merely drew the various conclusions in the process of reasoning.

It is repeated that this subject is a baffling one; so baffling, in fact, that it may take the combined experience of our outstanding men for, perhaps, a generation to gradually form a generally accepted decision. Thus, the value of this paper seems to lie in the fact that this new evidence secured under well-regulated conditions will assist in confirming our views on this subject of the relative values of cusp and cuspless posterior teeth under various conditions. It is a very commendable effort, and I am happy to be the first to congratulate the author.

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Read before the Academy of Denture Prosthetics, New Orleans, La., March 17, 1952.
Received for publication March 17, 1952.

MECHANICS OF DENTAL STRUCTURES: GUIDE TO TEACHING DENTAL ENGINEERING AT UNDERGRADUATE LEVEL

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"PROSTHETIC dentistry is practiced largely as an empiric art. Science seeks to rationalize and generalize facts in order to gain predictability. Objectivity and reliability are thus served, and the hazards of 'cut and try' measures are reduced to a minimum. Dentists employ much technology."[1] We can and should borrow the laws and principles of the more exact allied sciences to soundly base as many of our technical procedures as possible. This kind of reasoning has directed the writing of this paper.

Function determines form. This fact is generally conceded by artists, architects, engineers, scientists generally, and others—even Nature—who are concerned with such matters. The thing which determines whether a building has beauty, whether a vehicle has proper line, or whether the pianist addresses his instrument correctly is function. If a building serves its purpose well and economically, if the lines of an airplane promote economy and efficiency in flight, and if the posture of a pianist or golfer conserves his energy and facilitates efficient movement, the form in each case is accepted as proper. So, too, if the abutment inlays take the strains of a bridge in function without damage to themselves, the prepared teeth, or the cement, the inlay form or design is proper.

INTRODUCTION TO SUBJECT

In this paper, we will discuss inlays, bridges, and partial dentures. These subjects will not be treated in the orthodox manner, but rather as an engineer might present them. From this study, we will gain an insight into the behavior of structures and structural materials, derive a rationale of cavity preparation, reach definitive accuracy with respect to such things as "resistant" and "retentive" forms, and obtain valuable technical information which has everyday application to chairside and laboratory procedure.

Much of the material deals with engineering which may be new to the reader. The engineering material which shall be used, however, will be quite elementary. Engineering terms will be defined as they are used. Students with a good working knowledge of high school mathematics should have no difficulty grasping the context of this paper.

Read before the American Academy of Restorative Dentistry, Chicago, Ill., Feb. 2, 1952.
Received for publication April 29, 1952.

PROSTHETIC ENIGMAS

Have you ever stopped to think what happens when a patient bites on the bridge you placed for him? Why do so many bridges attached to two proximocclusal inlays fail? Why does a bridge with a crown at one end and a proximocclusal inlay at the other come loose at the inlay end? Why do tube teeth suspended from the framework of a lower bridge come loose but seldom break, while porcelain teeth used as upper pontics fracture frequently? Why is bone resorption so excessive on the "compression" side of the primary abutment of cantilever bridges in mouths of patients afflicted with periodontoclasia? Answers to these questions can be found in the study of the physics of materials and structures, otherwise known as engineering.

TORQUE AND BENDING

Torque and bending are largely responsible for the above failures, and to provide against failure from these causes cavity preparation and structural design must be proper. That torque and bending occur cannot be questioned.

At the World's Fair in Chicago in 1933 there was an exhibit in the Transportation Building which consisted of the following: Two short sections of railroad rails were placed parallel to each other but separated by about thirty inches. A third rail was placed crosswise upon these rails. All were eight-inch rails, the heaviest gauge in use. A micrometric indicator was attached to the bottom rails and adjusted to the bottom of the upper rail in such a way that as spectators went by they could put their hands upon the crossrail and, astounding to relate, with slight pressure they could bend the upper rail and read the amount of bending registered by the indicator. I was greatly impressed by the fact that I could bend the rail with the weight of my finger.

At the time, I was studying dentistry at Northwestern University Dental School, and my mind was still fresh with G. V. Black's data on the forces of mastication. I could not help but associate the bending of the rail under finger pressure with the bending of dental bridges. Here was a beam of steel eight inches thick bending under finger-tip pressure! What must dental bridges one-eighth inch thick be doing under, say, sixty pounds of biting force? I never forgot the experience. Later, when clinical experience forced me to look for explanations for my bridge failures, I gathered, bit by bit, through tapping the knowledge of my engineer friends and patients, improvised experiment, and library research, the information which I am presenting.

There is a generalization of fact which we all should know: "All bodies, however rigid or massive they may be, are beyond question deformed by the application of force. It does not matter how small the forces may be, the deformations are necessarily present. Mastication gives rise to forces which produce deformations of compression, tension, shear, deflection (bending), elongation, and torsion of highly significant magnitude in the investing tissues, the teeth, and the restorations."[4] In this article we will consider mainly the effects of these forces on restorations.

DENTAL CEMENTS

The deficiencies of dental cement also play a part in the above failures. In order to have a successful inlay, you must have a successful cementing or bonding job. The study of bridge or inlay function must be correlated with a study of the bond.

Dental cement is able to take great stress in compression, 13,000 psi (lb. per square inch), according to the National Bureau of Standards.[2] Even when the compressive forces of heavy mastication are computed against the small fractions of a square inch which the inlays or abutment castings present to this force, the safe load on dental cement in compression is probably not exceeded. If the abutment castings, however, are so designed as to place the cement in shear or diagonal tension, failure of the bond may occur because brittle substances like dental or structural cements are weak in these qualities. Pure tension probably never occurs in the dental bond because dental cements are not adhesive.[3]

Figures for shear or diagonal tension are not readily available for dental cement but, if dental cement resembles structural cement in its physical properties, it is probably less than one-tenth as strong in diagonal tension as in compression. But the dental bond is not even as strong as this comparison would seem to indicate for this ratio represents strength in bulk.

It is interesting to note, for purposes of analogy, that although structural concrete will take about 3,000 psi in compressive stress, engineers use 600 psi as a safe figure, 125 lb. in shear, and only 50 lb. in diagonal tension across a 45 degree angle. Figures for concrete in tension are almost never used, but sometimes 20 psi is applied for special structural conditions as in the footings of foundations when concrete is subjected to bending.

At this point I might define the term "shear." If a test specimen which is weak in tension (as cement or concrete) is supported as on a block and a weight or compressive force is placed upon the specimen along a plane directly above the edge of the support, the cohesion of the molecules of the specimen along this plane resist the weight. If the weight is powerful enough to overcome the cohesive force of these molecules they will "give up" or slip past each other, and the specimen will divide in two. This is shear, and a value can be assigned to the force necessary to produce shear in a given specimen. Now, if the weight is applied at some point removed from the support, the term applied to the test is diagonal tension, and the force necessary to produce a failure of the specimen is, as the above figures show, considerably less than the value for pure shear.

Dental cements act as bond by a keying action (Fig. 1). What we really have to consider is the combined strength of these keys to shear or diagonal tension. It is not clear whether the keys are in pure shear or whether, due to the shrinkage which occurs in the setting of all dental cements, they are in diagonal tension.[4] When a cemented inlay is placed in axial traction, the strength of the cement bond will be determined by the following factors: (1) Strength of the cement in shear. (2) Roughness of the interface between the inlay and the tooth. (3) Areas involved in the bond. (4) Pitch or taper between opposing walls of the

cavity. (5) Thickness of the bond. (6) Irregularities of the inlay and the tooth. This takes into account the dovetail. Since the center of retention of an inlay would only be coaxial with the resultant of retractile forces by rare coincidence, the net effect of a retractile force is torque.

"If it be assumed for a hypothetical case that the keying of the cement occurs at 90° to the retractile force, the relations of all the factors may be expressed by the equation[5]:

$$\text{Strength of the cement bond} = K \bullet f\left(\frac{n,c,A,1}{d}\right)$$

Where K = a constant denoting shear strength of the cement in bulk
n = number of the projections
c = a cross-sectional area of a projection
A = areas of tooth and restoration involved in the bond
d = distance between opposite faces of the bond

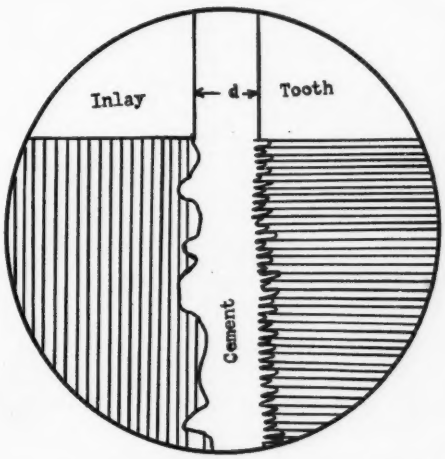


Fig. 1.—Schematic illustration of the factors which maintain the dental bond. (From J. D. Res. 27:651, 1948.)

"From the foregoing, n and c become progressively smaller values as casting accuracy and cavity rectitude improve. Since n and c are not at the control of the operator except in a negative sort of way, A and d are the important factors. Two important conclusions follow from this study: (1) It should be regarded as axiomatic that the coupling between the abutment castings and the teeth should be such that the deflection and torsion set up in the prosthetic structure place the cement under the abutment castings in compressive stress. [In other words, cavity preparation should be such that there is a mechanical coupling between the inlay and the tooth. We must not depend upon cement to take the stress in shear or diagonal tension except in direct axial traction.] (2) Prosthetic structures which subject the bond to great shear stress should be retained by rather large abutments such as the three-quarter or the full jacket."[4]

BRIDGE DESIGN

If we make use of the research of certain men, Stuteville[6] for one, we learn that the roots of teeth move in their sockets when load is applied eccentrically to the crown of the tooth. As a result of his studies, Stuteville reported that the roots do not move bodily but that they turn on axes of rotation which lie in the apical third of the roots of the teeth. In the case of multirooted teeth, the axis of rotation is in the bone septum between the roots of the tooth. When a lower molar is tipped mesially, the mesial root goes down while the distal root comes up slightly.

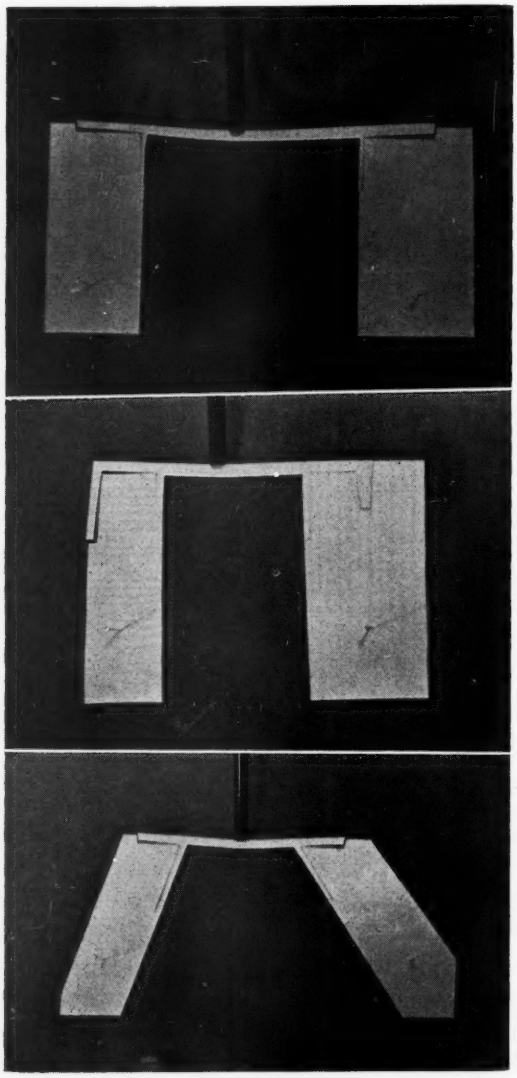


Fig. 2.—*A*, Cardboard model illustrating bridge deflection when abutments with thin flanges are used (pin-ledge, thin proximocclusals).
B, Cardboard model showing deflection of "MOD" type of abutment and immobilization produced by dowel at right.
C, Cardboard model showing deflection of bridge when supported on tipped abutments. (From J. D. Res. 27:658, 1948).

EXPERIMENT WITH CARDBOARD MODELS

If we make cardboard models[6] of teeth, and pin each model with a straight pin to a drawing board at this axis of rotation, and then place a cardboard bridge over these teeth, we can simulate and study the behavior of a dental bridge in greatly magnified size. For the present purpose, we can disregard the influence of the cement, just as the masonry is disregarded by engineers in the stress analysis of a steel-framed building. Let us not disparage this study, for the use of cardboard models is a device frequently used by engineers when they are studying unfamiliar problems. By this experiment, we find that the *cardboard models of the abutment teeth move very little* on their axes of rotation; *most of the movement is in the structure,* that is, the bridge or beam, and this movement gives rise to a characteristic pattern which can be seen in Fig. 2,*A* and again more strikingly in Fig. 4,*A*.

ENGINEERING EXPERIMENT I

A dental bridge is nothing more than a beam between two abutments, just like a plank across a creek or a structural bridge. The latter is only a very thick beam supported at the two ends or abutments.

If we take a beam which is freely supported at the two ends and load it with a weight (Fig. 3,*B*) the following happens: All the molecules comprising the upper half of the wooden slat shown in the figure are squeezed together or compressed, and all the molecules of the lower half are pulled apart or stretched. This compression or tension, as the case may be, is not uniform but varies progressively as one goes outward from the central plane. The compression or tension is greatest, therefore, in the outermost layers of molecules. The central plane of molecules is neither compressed nor stretched and engineers call this the "neutral axis."

The compressed side of a stressed beam is shorter while, due to the stretching, the tensed side of the beam is longer than in the unstressed state The neutral axis remains the same length whether the beam is stressed or passive.

ENGINEERING EXPERIMENT II

Proof That Deflection Varies as $\frac{1}{\text{Depth}^3}$ or Length^3

The slats shown in Fig. 3,*A* and *B,* are both cut off the same 2 x 4 in. piece of lumber. The only difference between them is that one is twice as thick as the other. The slat in Fig. 3,*A,* is approximately ¼ in. thick, the other, ⅛ in. From the photographs, something peculiar may be observed about bending. Within the elastic limit of any given material, bending or, as it is usually termed, deflection varies inversely as the cube of the depth and directly as the cube of the length.

This may be illustrated and proved thus: It should first be stated that the slats used in Fig. 3,*A* and *B,* were cut off exactly ¼ and ⅛ in. thick but in sandpapering the cut surfaces for ease of handling and to facilitate exact measurement, the thin slat ended up just a little under one-half the thickness of the other,

being, in fact, $\frac{1}{2.4}$. This will affect the results but is close enough to serve our purpose inasmuch as this test is only a specific illustration of a generally verifiable fact. The slats are freely supported on blocks spaced at 2 ft. and the same weight is placed upon each slat at its mid-point. It is important that blocks be used with square-cut edges because the edges act like the "knife edge" of a weighing balance. The thick slat in Fig. 3,*A*, bent down 0.2 cm. under this weight, the thin slat bent 2.6 cm. Using these figures to form a proportion:

$$\frac{1}{x} = \frac{0.2}{2.6}$$

$$0.2\,x = 2.6$$
$$x = 13$$

Then, using the thin strip when the blocks are moved from 2 ft. apart to 1 ft., (Fig. 3,*C*), the value for the deflection of the slat is 0.3 cm. By proportion again:

$$\frac{1}{x} = \frac{0.3}{2.6}$$

$$0.3\,x = 2.6$$
$$x = 8.66$$

The thin slat bent thirteen times as much as the thick slat, and it bent 8.66 times as much with blocks at 2 ft. as it did when the blocks were moved to 1 ft. With the explanation offered at the outset, these values are in keeping with the order of experimental error because if the necessary corrections are made we get: The thick slat measures 6 mm. in depth, the thin slat measures 2.5 mm.:

$$\frac{1}{x} = \frac{2.5}{6}$$

$$2.5\,x = 6$$
$$x = 2.4$$

$$\text{And since deflection} = \frac{1}{\text{depth}^3} = \frac{1}{\left(\frac{1}{2.4}\right)^3\left(\frac{1}{13.8}\right)} = 13.8$$

To put the results of the experiment more simply and exactly, doubling the length of the slat makes it eight times more flexible; and if the length of the slat remains constant, reduction of its thickness by one-half also makes it eight times more flexible. If the thin slat were one-third as thick as the other its deflection to the load would be:

$$\frac{1}{\text{depth}^3} = \frac{1}{\left(\frac{1}{3}\right)^3\left(\frac{1}{27}\right)} = 27$$

To bluntly bring this fact to apply to dental experience, all other things remaining equal, a two-tooth bridge will bend eight times as much as a one-tooth span, and a three-tooth span will bend twenty-seven times as much. We should take advantage of this fact. We want the metal parts of our bridges to be as thick occlusogingivally as possible, especially for long span bridges, to keep bending of the bridge span down so that the abutment castings will not be wrenched loose from the teeth; we want our abutment castings stiff so that they will not crumble the cement binding them to the teeth.

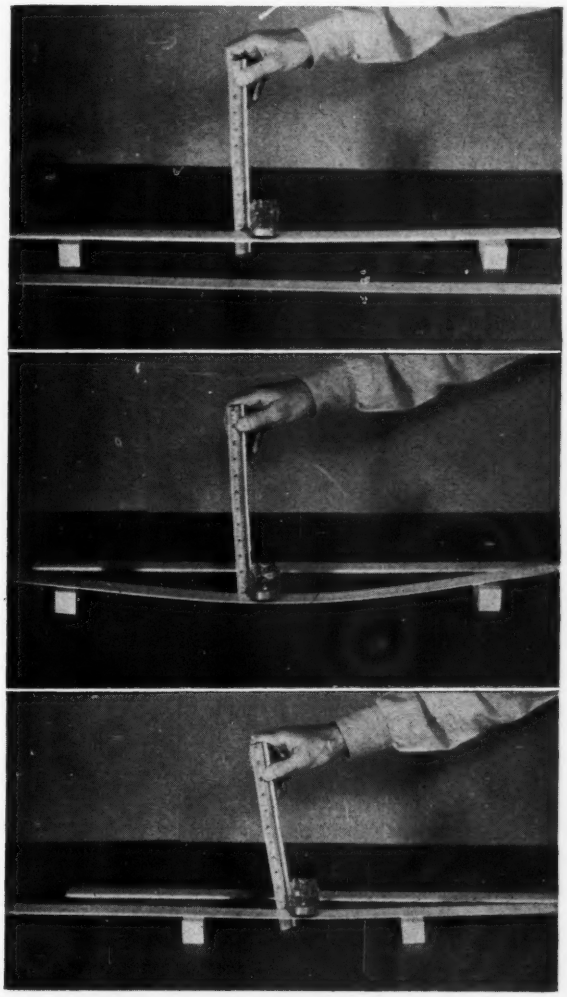


Fig. 3.—*A*, The deflection of ¼ in. slat to a given weight when freely supported. The supports are 2 ft. apart.
***B*, The deflection of ⅛ in. slat to the same weight with supports spaced 2 ft. apart.**
***C*, The deflection of ⅛ in. slat to the same weight with supports spaced 1 ft. apart.**
(From J. D. Res. 27:657, 1948.)

The rule that materials bend inversely as the cube of the depth and directly as the cube of the length is a law which holds for any substance whose modulus of elasticity in tension equals or approaches that in compression, and therefore applies

to all springy materials with which we are familiar, such as cardboard, bone, dentine, wood, steel, gold alloys, plastics, and, within a certain temperature range, even wax. This same relation of mass to length and depth holds as well for the components of the abutment castings, that is, the isthmus, dovetail, and box, as for the bridge span. The thicker the proximal box the less by a cubed power the bending of this component. The isthmus of a mesiocclusodistal is substantially more flexible than the isthmus of a proximocclusal inlay because it is longer; consequently, a mesiocclusodistal inlay has less resistance to displacement than a simple proximocclusal inlay.

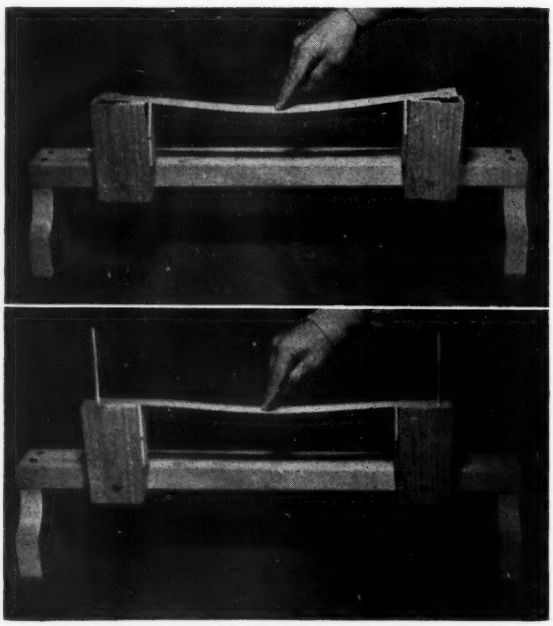


Fig. 4.—*A*, Wooden model illustrating characteristic deflection of fixed bridge. *B*, Same model as Fig. 4,*A*, demonstrating the efficacy of vertical dowels. (From J. D. Res. 27:659, 1948).

MECHANICS OF DEFLECTION IN DENTAL BRIDGES

Fig. 4,*A*, is a wooden model specially designed to reveal the deflection characteristics found in dental bridges. The analogues of teeth are the two upright pieces, each pivoted upon an axis of rotation approximating that found in human teeth. The "pontic" is made very thin so that it will be readily responsive to load. For purposes of simplicity the pontic is of uniform cross section, comparable to the sanitary bridge type of dental construction, and the abutments are simple proximocclusals.

From a study of Fig. 4,*A*, we can see that the isthmus and dovetail of each abutment casting may be looked upon as a cantilever beam; further, it is obvious that the cement under the dovetails and isthmuses is not in compressive stress, as generally conceived, but rather in tension (if tension were possible), whereas the cement along the sides of these components is in shear. This violates our earlier

axiomatic rule that structural design should be such as to produce a mechanical coupling between the metal and the teeth. Cement over any mechanically coupled parts would be in compressive stress which is the manner in which dental and structural cements takes stress best. From the cardboard model shown in Fig. 2,*B*, it can be seen that if the abutment casting is prepared as a mesiocclusodistal, the distal flange moves away from the abutment tooth so it also does not represent good engineering design.

Theoretically what occurs when beams are used in conjunction with columns or "compression members," as the proximal flanges of the abutment castings may be called, is a bending or bowing of the proximal flange of each abutment. This bowing takes the form shown in Fig. 5. The surface nearest the pontic is under compression; the opposite side (cavity side) is under tension; through the middle is the neutral axis. The bending moments of a bridge with both abutments fixed are greatest where the neutral axes of the flanges intersect the neutral axis of the beam.

Far from dragging the teeth toward each other as might be assumed, in actuality, under the circumstances shown in Fig. 4,*A*, the deflection of the pontic on concentrated loading tends to thrust the teeth apart, and the dovetails are raised out of their seats in the teeth. The only part of the bridge assembly which places cement under compression is the cervical floor of each abutment casting.

These considerations establish as sound and reasonable the preparation of cavities with large, flat, cervical floors, and with provision for a thick proximal flange. Abutments with very thin proximal flanges are inadvisable for the reason that such flanges will be easily deflected laterally when the bridge is in function, thus putting torque upon retentive features of abutment design. If pin-holding is used for retention, as in the case of a pin-ledge preparation, the retaining pins may be wholly inadequate to withstand the forces applied.

For physiologic reasons, it is desirable to cut abutment castings shallow. While it is inadvisable to employ a thin proximal flange for a primary bridge abutment casting of the proximocclusal type, and although the distal flange of a mesiocclusodistal preparation tends to separate from the tooth during bridge function, it is remarkable that compounding these features in the preparation of a three-quarter crown or full crown results in a very satisfactory abutment. The displacement of the opposite inlay flange can be prevented, and stiffness of the proximating flange of the abutment can be promoted simultaneously, when the flanges are united by an external strap or "web" as in the construction of a three-quarter crown. Metals take stress in tension very well. The three-quarter crown may be prepared with the lingual cusp coming through to conserve tooth structure, or it may be prepared in the conventional manner. An extremely rigid retainer is thus obtained with greatly augmented bonding surface.

When it is considered desirable to keep the primary abutment of a bridge as small as possible, good engineering design requires the use of a dowel. For the reason that such dowels are not to be placed close to the pulp, they usually take the form of semicylindrical extensions of metal from the dovetail which lodge in the surface of the buccal or lingual tooth structure. When the cervical floor of such a

semicylinder is lower than the pulpal floor of the preparation, it provides mechanical resistance to the displacement of the bridge even without cement. The efficacy of doweling practice is exhibited in Fig. 4,*B*. More will be said on resistance form later.

DEFLECTION AND TORSION

Up to this point we have been considering the bridge as being of homogeneous material and uniform section. "Dental bridges, while approximating this condition in some construction, are usually composites of gold alloy and porcelain or plastics. What has been written still applies in principle to ordinary bridge construction although the analytical problem becomes more complex. It must be obvious after even a cursory view that when porcelain, with a modulus of elasticity in the range of 16,000,000 to 45,000,000 lbs. per square inch,[8] is used for cosmetic purposes in bridge construction, the resulting pontic will be much stiffer than when plastic (methyl methacrylate), with a modulus of elasticity of 400,000 lbs. per square inch, is used.[9]

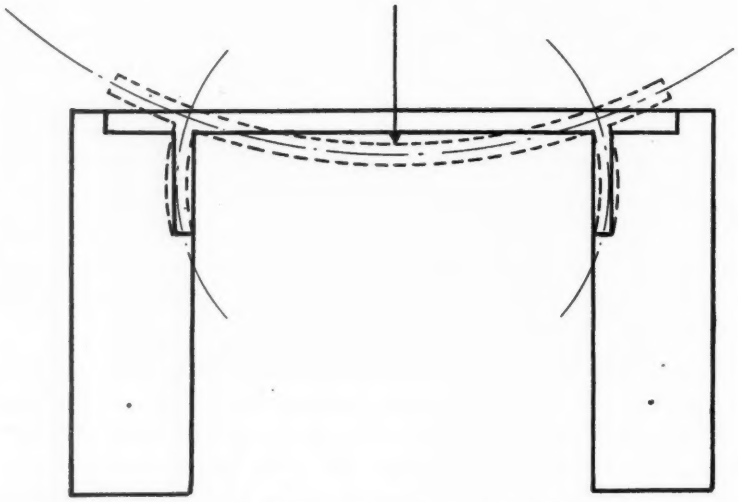


Fig. 5.—Deflection diagram of a fixed bridge.

"What is this modulus of elasticity, or Young's modulus, as it is sometimes called, and why is it important?

"Modulus of elasticity is a ratio of stress: strain."[11] It is usually written in handbooks on mechanics, $E = \frac{S}{\Delta}$. The ratio only applies within the elastic limit of a given specimen. Simply stated for the English system of units, the numerator of the fraction is the number of pounds per square inch which it takes to produce a given increase or decrease (depending upon whether the test is done in tension or compression) in the length of one inch of specimen. The denominator is the amount of increase or decrease. If the force required to produce the deformation is great, as in the case of steel, for example, the numerator will be a large figure while the de-

nominator will be a relatively small figure. When the arithmetic of dividing the large number by a small one is carried out, the quotient is a large figure, 30,000,000 lbs. per square inch for steel. When the numerator is a relatively small figure with respect to the denominator, as in the case of rubber, the resulting quotient is a low number. To the uninitiated it may seem strange to say that steel and partial denture gold have a high modulus of elasticity whereas rubber has a low one.[1]

The modulus of elasticity is important because it is a measure of stiffness just as feet and pounds are measures of length and weight, respectively. For our specific purpose here we can tell at a glance by the modulus of elasticity of a given specimen how it will behave as a veneering material in dental bridge construction.

"In addition to being a very stiff material, porcelain is brittle, so, like concrete and dental cement, it will do poorly in tensile stress. It finds its optimal application in bridgework when used on the occlusal surface with the structural framework on the tensile or tissue side. This is analogous to concrete-slab construction; the load-bearing part of the slab is on the compressive side of the neutral axis, whereas the re-enforcing rods are on the tensile side. For esthetic reasons, this kind of construction is not acceptable for upper bridges because the 'boxing' or 'cradling' necessary to support the porcelain would place metal on the conspicuous buccal surfaces.

"It is easy to see why porcelain fractures when used in the orthodox manner in upper bridges. Since the masticatory cycle consists of a horizontal as well as a vertical movement, the buccal cusps of upper bridges often come into heavy stress with the result that the gold alloy overlaying the porcelain is frequently stretched or peened out when the bridge is in use, often to a thin fin which can be observed extending out beyond the tip of the porcelain. This is most noticeable if the occlusal surfaces are not drafted properly in eccentric position and opposite cusps meet end to end. The stretching of the buccal cusp tends to bend or deflect the porcelain at the point of its retention. Since porcelain will only take a very limited amount of tension, fractures across the pins or post must be expected."[11]

On the other hand, if the porcelain pontic is suspended from an occlusal framework as in lower bridge construction, the deflection of the beam tends to pry the porcelain off especially if the metal structure is expanded by the chewing of heated food.[1]

"In view of the high flexibility factor which holds with respect to increasing the length and decreasing the depth of section, the reason for the failures of the early types of plastic bridges is apparent even when such bridges were used for little more than adornment. Originally, plastic bridges were processed around a notched retaining bar which was attached to the abutments by soldering. The bar was frequently quite long, as when used in cuspid to cuspid bridge construction, and although turned edgewise it was nevertheless quite thin incisogingivally. Since a bar of such dimensions would very likely be quite flexible, and since the plastic overlaying the bar was relatively soft and yielding (modulus of elasticity, 400,000 lbs. per square inch), the structure deflected

excessively in use, fatigue of the materials took place in a short time, and the plastic cracked off or pulled away from the framework. When plastic is used as a veneering material, the metal framework should be made thick enough occlusogingivally to restrict excessive deflection."[1]

Conclusions from the study thus far are that we need strong abutments for long span bridges because of the tendency to wrench the castings loose from the supporting teeth. We should have square-cut, shallow, but extensive abutment preparations for bridgework, and this lends support to the indirect system of fabricating inlays because thin patterns for castings are best handled by indirect methods. This also means, however, that we have to have a good impression-taking and converting system because, from the formula $\left(K \cdot f[n,c,A,\frac{1}{d}]\right)$ the strength of the bond is closely related to the tolerance between the casting and the tooth.[1]

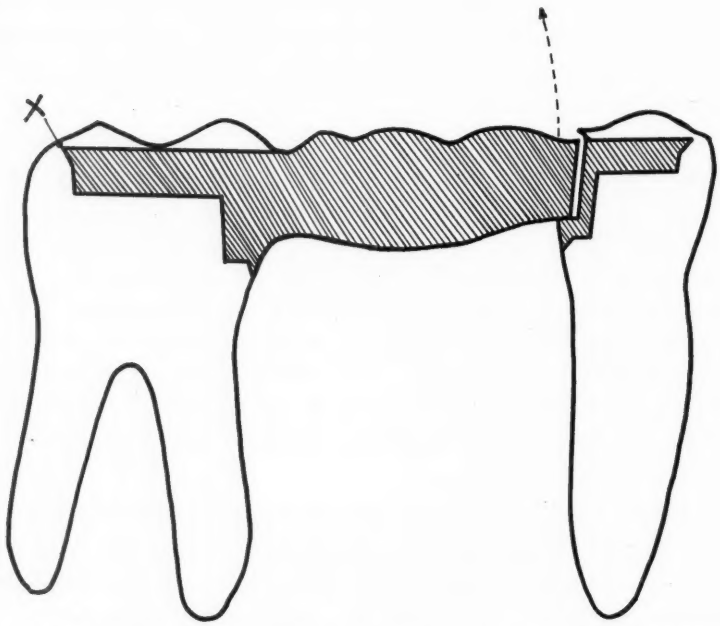


Fig. 6.—"Negative" intermaxillary torque produced by chewing sticky food upon the cantilever. (From J. D. Res. 27:652, 1948.)

INTERMAXILLARY TORQUE

We have considered deflection as a factor in the mechanics of dental structures; let us now consider torque. Torque is force acting through a moment arm which tends to produce rotation about a given axis or point. Intermaxillary or mesiodistal torque may occur as a result of the positive as well as negative forces of occlusion (Figs. 6 and 7). When one chews sticky food with a posterior cantilever bridge, the negative forces acting on the pontic can be ex-

pressed as a single resultant force which tends to pull the lug out of its seat in the secondary abutment and apply torque to the primary abutment. The axis of rotation or fulcrum is denoted by *X* in Fig. 6. In the positive phase, if tough fibrous food, such as the crust of bread, is chewed on a posterior cantilever bridge, the unground cusps of the primary abutment tooth may engage the crust first, and great force may be brought to bear upon them before the bridge structure comes into occlusion. If this occurs, the primary abutment tooth may be depressed momentarily on the axis of rotation previously mentioned, *Y* of Fig. 7. Since the cantilever is being supported at the other end, and since it is conceivable that this end may not be depressed at all by the act, the net result will be a torque upon the primary abutment which will tend to pry the bridge cantilever off the tooth identically as the first illustration.

What will restrain the bridge from being pried off the primary abutment?

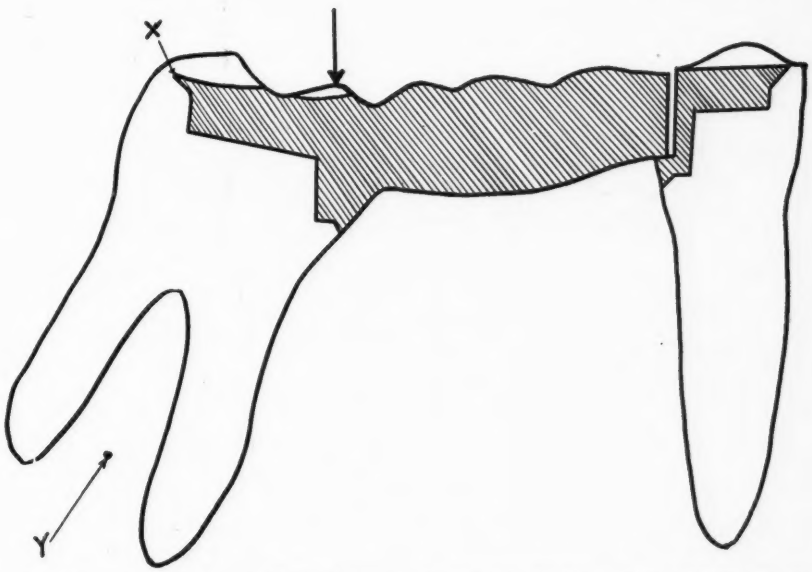


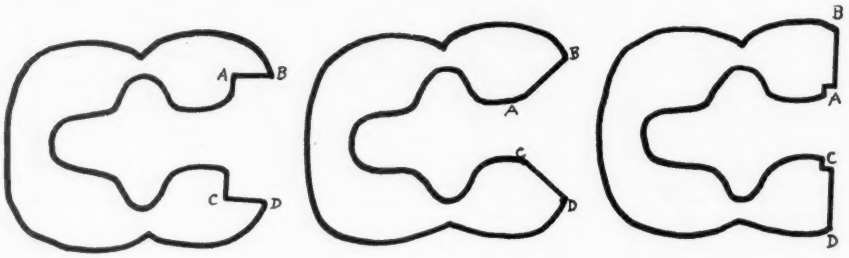
Fig. 7.—"Negative" intermaxillary torque. Counterclockwise rotation with *X* as center occurs when mastication of tough or fibrous food is borne by the cusps of the abutment tooth. The torque tends to pry the bridge structure off the tooth. (From J. D. Res. 27:652, 1948.)

RESISTANCE FORMS

If we analyze the resistance units of a simple proximocclusal primary abutment to torque from the above cause we have: (1) The bond between the proximal flange and the tooth will resist the displacement of the bridge. Obviously the more nearly the proximal flange is cut as a box with parallel and opposing walls the stronger the bond, (Fig. 8, *A*). Black's box preparation (Fig. 8, *B*) is nearer the ideal than the slice preparation (Fig. 8, *C*). In the extreme slice preparation, there are no opposing walls for these are set at 180 degrees with respect to each other. (2) The isthmus resists the displacement of the cantilever. The isthmus, however, is tapered, is relatively small, and is effec-

tive to a degree only as great as the strength of the cement to shear. Since the displacing force is relatively powerful and, furthermore, enhanced by leverage, the strength of the cement in shear over such small bonded area is not significant. (3) The dovetail resists the displacement. The dovetail is probably the most important factor in maintaining retention. It can be easily proved, however, that the dovetail may be ineffectual for the purpose. Its efficacy is determined by the degree of taper or "draft." It can be stated in substance that there is a critical pitch for the dovetail cavity walls which must not be exceeded or the dovetail loses all mechanical resistance to displacement.

Fig. 9 may be used to illustrate whether the dovetail will mechanically resist displacement of the cantilever to torque. Fig. 10 represents a sagittal section at a plane where the dovetail of the primary abutment is locked in tooth structure, and Fig. 9,*B*, is an enlargement of the dovetail area at this plane. The model used for Fig. 9,*B*, is made of plywood. A hole is drilled into the upper edge of the block which represents the dovetail at its mid-point (Fig. 9, *A*) to receive the spring-wire rod which will be used to impart torque to dovetail *A*. Fig. 9,*C* and *D*, is similarly prepared.



A. *B.* *C.*

Fig. 8.—Diagram illustrating relationship of "box" walls to cement bond.

Fig. 9, *B*, demonstrates by the deflection of the rod that a dovetail with no pitch is effective coupling to resist torque set up by the counterclockwise movement of the rod, whereas Fig. 9, *D*, demonstrates that a dovetail with the pitch shown by dovetail *B* will rotate freely to the same force upon a fulcrum established at *X*.

Fig. 9, *C*, illustrates that a dovetail with the degree of pitch shown by dovetail *C* is also effective in resisting counterclockwise torque.

"This experiment demonstrates the fact that for a given fulcrumage [*X* in each of the above cases], there is a critical pitch which cannot be exceeded without sacrificing mechanical resistance, but, most important, the experiment furnishes us with a tool which has general application and can be used to analyze any case diagrammatically for critical pitch. For instance, if the divider is placed at the fulcrum and the point of greatest rotation of the dovetail opposite is used to establish a radius, *Y* [Fig. 9, *E*], one may tell at a glance whether the critical pitch has been exceeded or not by the arc struck from these points. If the arc passes through tooth structure [Fig. 9, *E*], the dovetail has mechanical resistance; if through the inlay or cement [Fig. 9, *F*], it does not."[4]

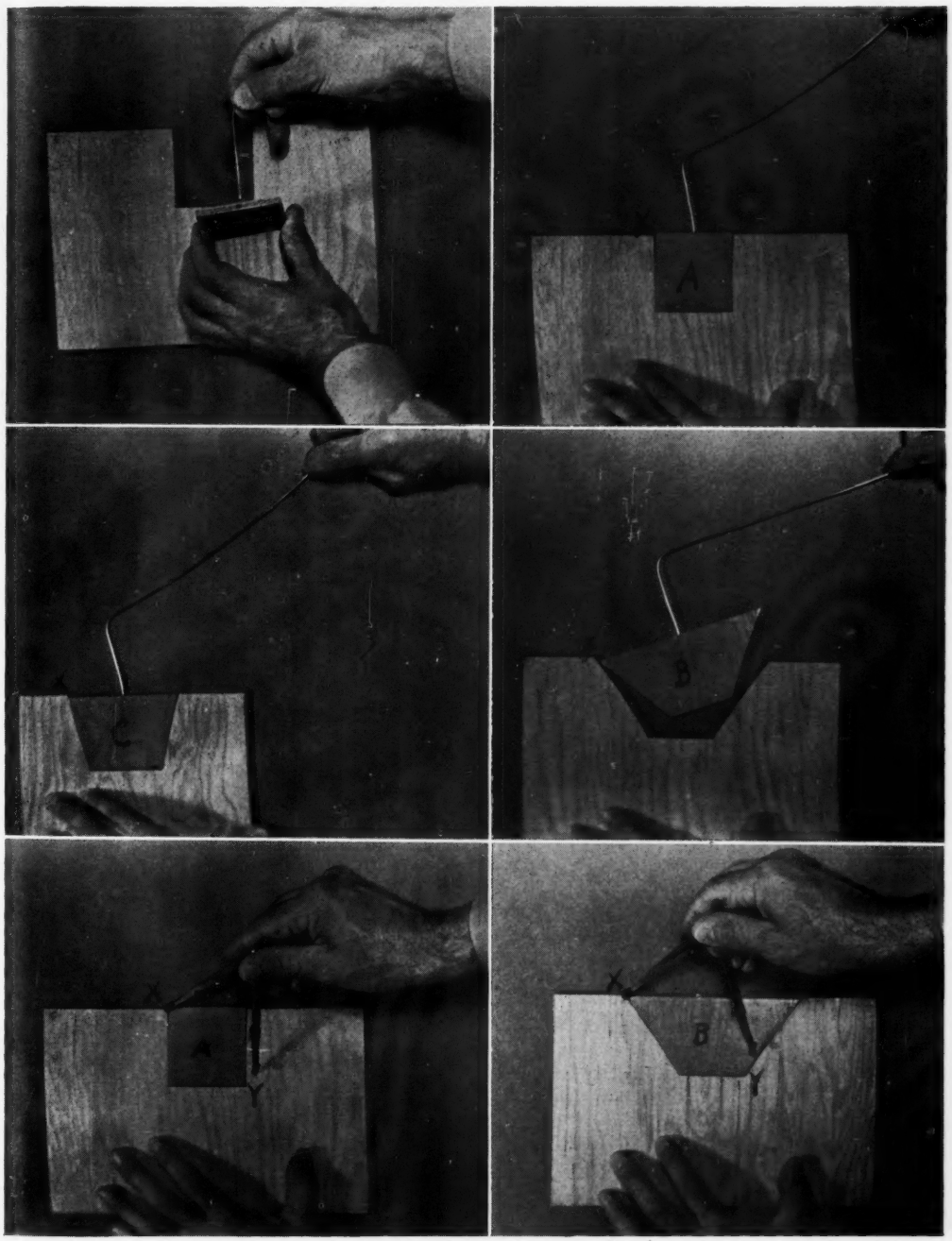


Fig. 9.—*A*, Close-up of model construction.
***B*, When fulcrumage occurs at *X*, a dovetail with no pitch is effective in resisting torque.**
***C*, Dovetail with this pitch does afford mechanical coupling.**
***D*, This dovetail affords no mechanical coupling.**
***E* and *F*, Experiment establishing the use of the radius for the determination of critical pitch.**
(From J. D. Res. 27:654, 1948.)

From the study thus far it is interesting to note that if the bridge ended at *X* (Fig. 10), the dovetail would provide mechanical coupling as borne out by arc *XA* which passes through tooth structure. Good surgical technique, however, would require extending the inlay to include all of the occlusal fissures. When the primary abutment terminates at *Z*, however, the pitch of the dovetail becomes more critical, and a dovetail with the pitch illustrated would be ineffectual in mechanically resisting the torque as borne out by *ZA*. From Fig. 11 we can see that reverse beveling of the gingival floor would also be ineffectual.

As an interesting corollary to this study, let us assume that the dovetail would be square cut enough to provide effective mechanical coupling for the cantilever bridge shown in Fig. 7 and, to make the illustration as extreme as possible, that the primary abutment is prepared as a slice preparation so that little bond exists between the proximal flange and the cavity walls. Since the isthmus is the most necked-down and, therefore, weakest part of the bridge structure, is it not conceivable that, when heavy force is borne by the unground cusps of the abutment tooth, the tooth may be depressed on its axis of rotation and bending can occur across the isthmus? When operative and surgical measures are not at fault, undoubtedly this is responsible for the recurrent caries sometimes seen under the gingival margin and along the axial surface of the flange of the primary abutment casting, even though the bridge may still be tight to testing. Emphasis is once again placed upon the need for external bracing of the isthmus and flange which is ideally done in the three-quarter crown preparation. Where the proximocclusal abutment is to be used as a primary abutment, the bucco- and linguoaxial line angles of the box should be grooved to provide mechanical coupling of the flange.

From the study of bridge deflection, we know that a fulcum occurs at the intersection of the neutral axes of the proximal flanges with the beam. Fig. 12 shows by arc analysis that the pitch of the dovetail walls becomes very critical to offset displacement by this kind of force. The diagram reveals very clearly how placement of a lingual or buccal groove provides resistance form.

MECHANICS AND BIOLOGY[1]

It is well known to dentists, clinically, that there is an important correlation between biology and mechanics. The biologic import of the mechanical differences among a fixed and a cantilever bridge and other prostheses will now be considered.

"From the study with the cardboard models, [Fig. 2, *C*] it is surprising to discover that even greatly tipped abutment teeth do not move toward each other, as might be expected, under heavy occlusal loading on the pontic. While it is common practice to employ cantilever construction for bridgework where the abutments tip toward each other in order to facilitate cavity preparation and placement of the prosthesis, from the experiment it would seem that tipped teeth require fixed or rigid coupling of the abutment castings because the fibers of the periodontal

membrane are placed more nearly in pure tension. A schematic deflection diagram to illustrate the conditions of concentrated vertical loading on a fixed bridge is shown in Fig. 13. Contraflexure occurs at *X* and *Y*. If the abutment castings hold to the shearing action on the cement, the deflection of the pontic produces a bending or bowing of the abutment teeth. Since teeth have considerable stiffness and mass, and since the shortening of the pontic caused by deflection is ordinarily of a low order, the significant force transmitted to the supporting teeth is axial. This tends to stretch the periodontal fibers and these in turn pull upon the alveolar bone to put it in tension. The situation is one approaching that of the bending of a lower molar when concentrated biting force is borne in the central fossa between the two separate roots of the tooth."[1]

Fixed bridgework can be looked upon in this light as approaching the physics of Nature's pattern.

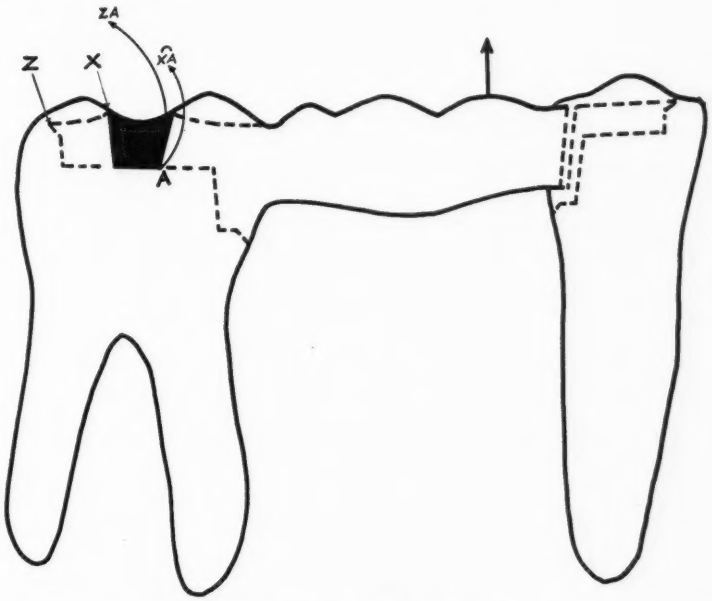


Fig. 10.—Demonstration of the critical pitch of the dovetail with respect to the fulcrum. (From J. D. Res. 27:653, 1948.)

Movement of teeth must occur across a mesiodistal axis of rotation as well as a buccolingual axis, and perhaps any number of axes between these extremes. All human teeth exhibit arch form. As a general rule, this means that the vertical axis of all teeth anterior to a given tooth will be medial (with respect to the median sagittal plane of the body) to the posterior one. When any two teeth, then, are united by a rigidly coupled prosthesis, foundation stability is promoted to resist horizontal force components because, when medial horizontal thrust is put upon the fixed bridge, the medial root has to go down while the lateral root (or roots) come up. The rotation takes place upon an axis lying in the edentulous bone between the two teeth.[1]

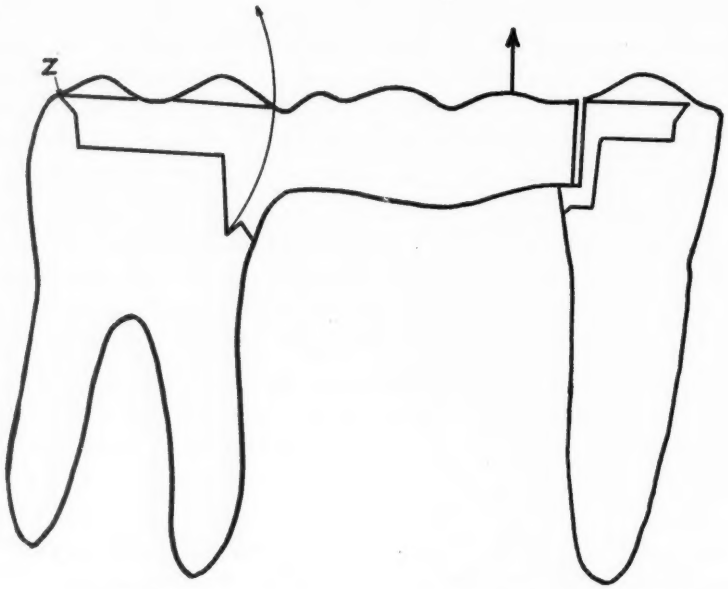


Fig. 11.—Diagram showing that reverse beveling fails to provide resistance form to displacement by torque when fulcrumage occurs at *Z*. (From J. D. Res. 27:655, 1948).

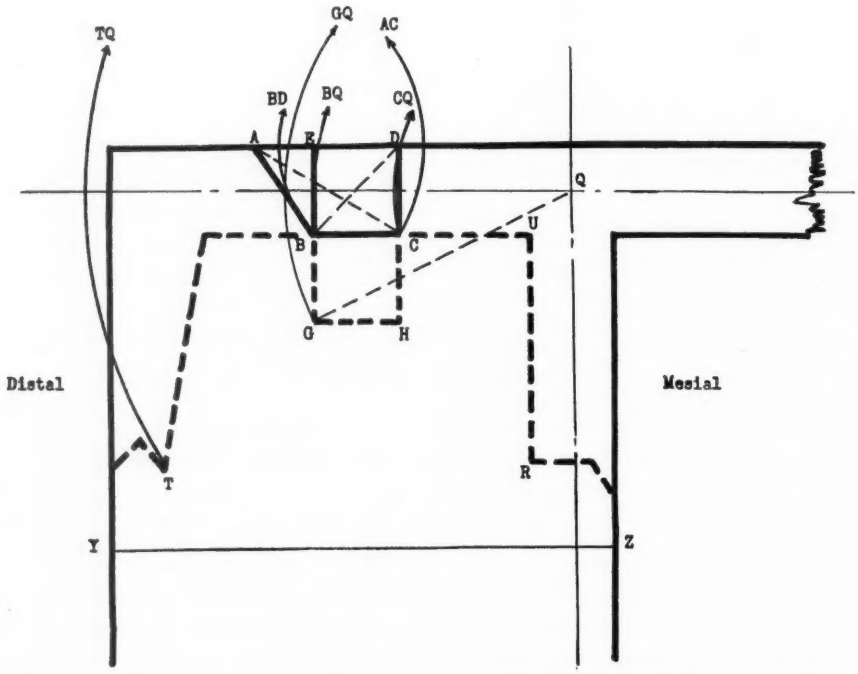


Fig. 12.—Diagram summarizing the critical pitch of the dovetail when torque produces fulcrumage at *A*, *D*, or *Q*. (From J. D. Res. 27:659, 1948.)

The foundation stability of the cantilever type of construction is not nearly as satisfactory. Usually there is sufficient movement in the lug to permit simple hinge movement buccolingually to horizontal force components, and to a less degree this may also be true in the mesiodistal plane. The looseness of the lug at the secondary abutment permits this tooth to turn distally on its axis of rotation due to the eccentric loading on the lug. It is generally recognized that excess compressive stress on periodontal tissue is a pathognomonic force, and injurious to the health of the investing tissues. If the loose coupling permits simple hinge action, excessive movement at the axis of rotation of the primary abutment will take place to horizontal forces. The movement will be progressively greater from the axis occlusalward and in the same order though in a reverse direction from the axis to the apex of the root. We can expect bone resorption to be greatest where the compression of the periodontal membrane is greatest and, of course, this is the clinical picture of the damaged investing tissues associated with cantilever bridges in the mouths of patients susceptible to periodontoclasia. Bridgework with rigid couplings is indicated for patients with poor periodontal metabolism.[1]

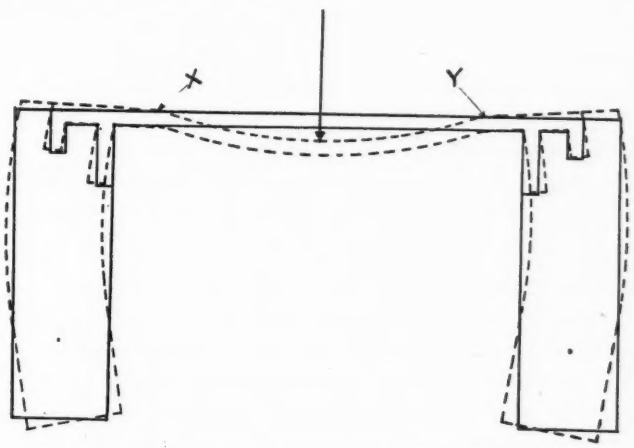


Fig. 13.—Schematic deflection diagram illustrating the effect of concentrated vertical loading on a fixed bridge. Contrafiexure occurs at *X* and *Y*. (From J.A.D.A. 44:189, 1952.)

Tipped teeth are weakened as prosthetic supports. Vertical loads upon bridgework supported on inclined roots resolve into large compressive as well as tensile forces on the periodontal membrane. Adding a cantilever to the physiologic difficulty of a tipped tooth pushes it farther downhill. In cantilever construction, most certainly a highly tapered lug should not be put into the tipped distal abutment for, due to the natural tendency which all teeth exhibit to mesial drift, the distal abutment will tip farther and turn out of contact with the base of the lug. Most of the cantilever support will be borne by the smaller abutment.

Clasp type partial dentures employing shallow occlusal lugs fail to make the most of the foundational capacity of the investing tissues of any given case. Each clasped tooth is free to turn on its axis or axes of rotation to horizontal forces. Where the demands of the case are beyond the scope of restitution by fixed bridges, the precision attachment type of partial denture is the next best choice and retains most of the desirable features of fixed bridgework.

TEMPERATURE AND METALLIC FIXED PROSTHESES[1]

"All tooth-borne castings except a simple occlusal or other single-surfaced inlays and a complete jacket contain components of an internal and external fit. The occlusal inlay is retained purely by fit within the tooth; the crown is an example of pure external fit. The dovetail and isthmus of a proximocclusal inlay are retained by internal contact, while the flange or flared box makes external contact. Similar relations can be found for all other proximocclusal inlay types including the three-quarter crown.

"Metals conduct temperature changes more readily than mineral matter. When cold foods are eaten, an occlusal or other single-surfaced inlay will pick up and transmit the cold faster than tooth structure, and it will shrink away from the tooth structure which supports it. Heat, on the other hand, will expand the inlay and bind it more tightly in the cavity. Difficulty with retaining Class I and Class V inlays is experienced clinically. Cold, and not heat, is responsible for these failures. Proximocclusal inlays do not fail in either heat or cold because, since the thermal shrinkage of the inlay is uniform or proportional to cold, the isthmus shrinks in proportion to its size. This has the effect of pulling the dovetail and proximal flange toward each other and a considerable part of the tooth and cement are thus under compression during the shrinkage. Since the compression of the tooth between the dovetail and the flange is of a low order, the tooth is elastically deformed and, as soon as the cold environment leaves, the tooth and inlay return to normal dimension."[1]

In the case of the inlay involving only one surface, the thermal shrinkage of the gold produces no compressive stress in the tooth structure, and when the oscillation between thermal shrinkage and expansion is repeated a number of times the interlocking cement keys are completely crumbled. It is interesting to reflect that soft gold occlusal inlays do not fail as readily as the inlays of the hard gold alloys. The reason for this can be found in that the occluding cusps of the dentition peen or spread the gold just as a foil plugger does in placing a gold-foil filling. That this occurs can be readily verified by observing the flattening of the inclined planes of the inlay and pitting of its surface. The "spread" inlay now elastically deforms the tooth so that the tooth maintains a mechanical grip upon the inlay just as the tooth does with respect to the foil. The elastic deformation retained by the tooth permits it to follow and hold the inlay when cooled.

The gold crown, of course, since it is externally retained, does just the reverse of the occlusal inlay. Upon cooling, the crown squeezes and compresses the tooth structure; but upon heating, the circumference of the crown becomes greater and it must expand away from the tooth. It is remarkable that substrate and organisms do not enter into the space so formed to produce recurrence of caries. One would expect that capillarity would furnish the mechanism to advance the deteriorative process.

Gold expands about 0.0000083 inch per degree Fahrenheit. If a gold crown is subjected to the extremes of ice water and freshly broiled steak, the temperature range to which the crown would be subjected could easily be 100°F., and

its expansion from the cold to the heated state would be 0.00083 inch per inch. If the crown measures ½ in. in diameter, its diameter would be 0.000415 in. bigger in the heated state. Microorganisms often associated with dental caries may range in size from 0.5 to 6.0 microns. (*L. acidophilus* 0.6 to 0.9 × 1.5 to 6.0 microns, *Str. salivarius* 0.6 to 0.8 micron, *Staph. aureus* 0.8 to 1.0 micron, *Staph. albus* 0.6 to 0.8 micron, *Bact. coli* 0.5 × 1.0 to 2.0 microns, etc.) A bacterium 2.5 microns in length is 0.0025 mm. or 0.0001 in. long. Obviously the microorganisms are smaller than the space provided by the expanded crown.

Tooth structure and dental cement conduct heat rather poorly. We often employ dental cement as a base for its thermal insulating quality. We would expect that it would not readily follow the crown in its dimensional fluctuations to temperature changes. It should be stated, however, that while the rate of thermal conductance varies greatly between metals and mineral substances, the coefficient of thermal expansion may be very close. Thus while the coefficient of thermal expansion of steel is 0.0000065 (6.5×10^{-6}) per degree Fahrenheit, the thermal expansion of concrete is 0.0000079 (7.9×10^{-6}). The coefficient of thermal expansion of tooth structure across the crown according to Souder and Peters[10] is 11.4×10^{-6} while gold is 14.4×10^{-6} per degree centigrade. What most likely occurs when a gold crown is heated, as in chewing hot food, is that due to an interchange of heat between the crown and the tooth, which acts to stabilize the dimensions of both, the outside of the crown is at a higher temperature than the inside. A temperature gradient is thus established across the crown. The tooth acts to cool the crown and greatly restricts its expansion while the heat of the crown expands the tooth. Analogous temperature gradients, for instance, occur across the oil film between the metals of the cylinder and piston of the internal combustion engine only that, of course, the heat is on the inside instead of the outside.

When inlays and crowns support bridgework, temperature changes may be responsible for some bridge failures. Since temperature variations produce changes in the dimensions of the pontic as well as the tooth-borne castings, the proportionately greater dimensional change of the mass produces deformations which should be taken by the abutment castings in such a manner as to subject the abutment to elastic deformation. This requires good metallic coupling. Again, the simple proximocclusal abutment may be deficient to furnish the necessary coupling.

COMMENT[1]

Where stiffness is needed in a dental fabrication, as much metal as possible should be placed above and below the neutral axis as structural needs would warrant. An upper partial denture which fits between two posterior teeth on one side and has a saddle extension over a completely edentulous posterior region on the other is a good example to illustrate the point. Since it is desirable to resist as much of the torque of the "pontoon" side as possible by the molar tooth of the other side, the bar portion across the palate should be stiff. This is ideally accomplished by using a double bar. The anterior bar is usually at a lower level

than the posterior bar, and often it is turned to present a slight vertical axis. The neutral axis of this structure runs through the open part between these two bars, so the greatest amount of stiffness is provided with a given amount of metal. We have all used this device empirically for a long time. Our analysis serves as an intellectual basis for our actions.

In fixed bridgework, when the bite is close, our analysis points out that we should not divide the available vertical intermaxillary dimension between the gold and porcelain or plastic unless the porcelain is used on the compressive side of the pontic. Otherwise, it is better to use the entire vertical dimension for the metal structure with a porcelain facing for esthetics.

"Three-quarter crown preparations for cuspid teeth are sometimes a problem. Since the vertical dimension is often very close in lateral excursion over these teeth, and since the size and cone shape of these teeth require a minimum of sacrifice of tooth structure, grinding must be done judiciously. In the case of the lower cuspid, the envelope of gold can be thickened for stiffness by slight exaggeration of the cingulum in forming the pattern, but for upper cuspid preparations it is often desirable to dress off the lower cuspid to provide a sufficient thickness for strength. Centric occlusion should be carefully restored in the casting to prevent subsequent extrusion of the lower cuspid."[1]

On the other hand, if we want to take advantage of the flexibility of a material as in the making of a clasp we should use thin sections. Dentists who employ dental compound for inlay impressions should select tightly fitting impression tubes and use the minimum of compound to secure registry of the axial portions of their preparations, for such impressions are more flexible and less likely to be permanently deformed in removal from slight undercut.

RATIONALE OF CAVITY PREPARATION[1]

"The rationale of inlay cavity preparation should take into account biology, physical properties, structural demands, and economy. In addition the usual demands of sound operative dentistry have to be met. Thus, somewhat more specifically, the following considerations further modify inlay cavity preparation:

"1. The cavity preparation for inlays must have "draft" to insure accuracy in the fit of the castings. While a certain amount of pitch in the cavity walls is essential, it is easy to destroy resistance form by too much taper.

"2. The cavity preparation should be conservative of tooth structure and all related dental tissues. It is important not only to provide a substantial inlay or abutment casting but also to leave enough tooth structure behind for a substantial foundation.

"3. The preparation should incorporate surgical principles to protect the teeth against recurrence of caries and to insure immediate and future health of the pulp. This means that, for primary abutment purposes, the cavity preparation should be relatively shallow but extensive. This is particularly important if the cavity preparation must be done in young teeth but it is also important if the preparation is to be done in old teeth which are unfilled, unabraded, and

noncarious. Fig. 14 illustrates dramatically the need for shallow preparation. When teeth become uncomfortable following large operative undertakings, the cause can be attributed either to injudicious use of rotary tools or phosphoric acid irritation from the cementing procedure.

Fig. 14.—Inflammation and necrosis under dentinal tubulae of deeply prepared cavity. This occurs whether cavity was filled with silicate or zinc phosphate cement. (Photograph courtesy Dr. H. A. Zander; from J.A.D.A. 44:193, 1952.)

"4. The cavity preparation should permit restoring the remaining portion of the tooth to the original or a functional form, and the casting placed over the preparation should strengthen and insure the serviceability of the remaining tooth structure. An intracoronally retained abutment should not be used on a badly mutilated tooth when with less grinding a more substantial casting can be obtained extracoronally.

"5. The preparation should be such as to make the inlay esthetically acceptable.

"6. The cavity preparation and subsequent procedure should be accomplished easily and inexpensively.

"7. The cavity preparation should conform to engineering principles so that structural demands upon the physical properties of the tooth and the restorative materials shall be properly met."[1]

The author wishes to acknowledge deep gratitude to Fred Best, structural engineer, and Charles Betzner, chemical engineer, for their interest and assistance in making this study possible.

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TEMPORARY ACRYLIC FIXED BRIDGEWORK AND SPLINTS

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IN A previous paper[1] a technique for the lining up of multiple abutments was described. The problem of temporary crowns, the temporary replacement of missing teeth, and the temporary splinting of teeth, particularly in anterior areas, had always been a bugaboo to the dentist before the advent of plastics. The development of heat-cured and more recently "cold-cured" resins has opened avenues for expedient temporary patient service during reconstructive work. Patients are more comfortable between visits; they have more esthetic temporary replacements with heat- and cold-cured acrylics than any other material previously afforded.

Fundamentally, temporary acrylic crowns, bridges, or splints may be classified as those made with cold-cured acrylics and those made with heat-cured acrylics. The former are constructed in the office, directly in the mouth immediately after the preparations are made, in one patient visit. The latter are constructed in the laboratory, either prior to the mouth procedures or immediately after most or all the preparations are completed.

Three techniques, namely the plastic crown form, the aluminum shell, and the alginate, and variations of each, will be described with the use of cold acrylics.

THE PLASTIC CROWN FORM

Ready-made plastic crown forms are available for all teeth in various sizes and shapes. For any prepared tooth, choose the proper plastic crown form, trim it to fit, make a thin mix of cold acrylic of the shade of choice, tamp it lightly into the crown form, being careful not to trap air, and seat it in place on the previously lubricated tooth. The acrylic mix must be thin, otherwise the seating force will split the crown form. When the crown form is seated, trim the excess acrylic at the gingiva and allow it to set. If the crown seems very tight after removing and reseating it, ream out the inside slightly with a No. 6 or No. 8 round bur, otherwise the temporarily cemented crown will be difficult or impossible to remove without injuring the tooth. If two or more adjacent teeth are properly lined up, and need temporary splinting (Fig. 1), cut individual plastic crown forms for each tooth, and make puncture holes at the contact points. Fill each crown form with acrylic, and seat all of them on the lubricated preparations. Add more acrylic externally at the contact points where the acrylic oozes

Received for publication March 27, 1952.

through, and saturate the contact areas with monomer to assure a good chemical union. After the acrylic is set, remove the crowns, trim the gingival margins, and polish. Ream out the insides of the crowns, if necessary, and cement them with a temporary cement.

An alternate method is to trim all of the plastic crown forms and seal them to each other at the contact points with cold acrylic while they are held in place by occlusion and before filling them with acrylic (Fig. 2). After the acrylic is set, remove them as one unit. Fill each crown form with cold acrylic and seat them with the aid of the occlusion. Trim the excess acrylic at the gingival margins and allow it to set.

Fig. 1.

Fig. 2.

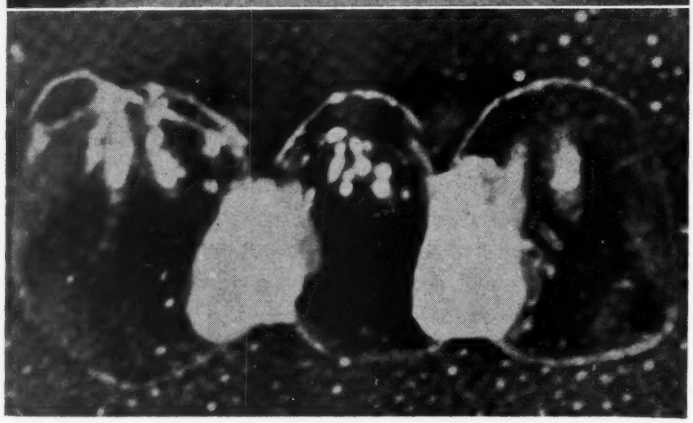


Fig. 1.—The temporary splinting of six upper anterior teeth in two sections. |1, |2, and |3 plastic crown forms were filled individually first, seated, and then sealed together at the contact areas. 3|, 2|, and 1| plastic crown forms were sealed at the contact points first, then filled, and seated to place.

Fig. 2.—Plastic crown forms sealed together by acrylic at the contact areas.

If undercuts or nonparallelism are known to exist between the preparations, limit the acrylic to the labial or buccal surfaces only, for esthetics, allow it to set in the mouth, remove the crown forms, and cement them with temporary cement. The temporary cement will fill in the otherwise interfering discrepancies and provide for their subsequent removal.

A missing tooth may be replaced by a properly selected stock acrylic tooth, or by a filled-in plastic crown form which has been roughened at the contact areas to provide for good union. The temporary pontic is sealed to the adjoining crowns on each side, as above.

Fig. 3.

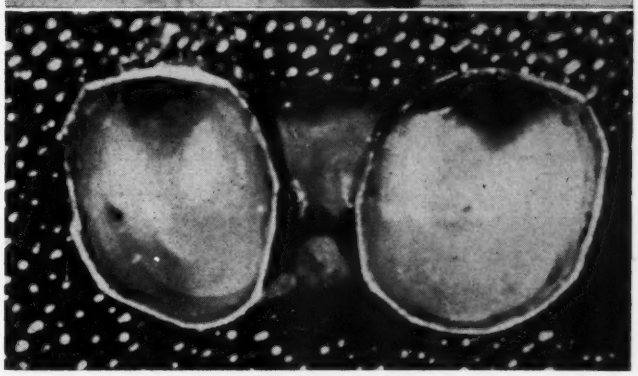


Fig. 4.

Fig. 3.—Temporary aluminum crowns splinted together. Note the excess of acrylic at the contact area.
Fig. 4.—The internal view of the acrylic confined to the occlusal third of the crowns, and the excess acrylic at the contact areas.

ALUMINUM SHELL CROWNS

Aluminum shell crowns are suitable for temporary splints for posterior teeth. To use them, cut holes with a No. 8 round bur at the contact areas. Fill the occlusal third only of each shell with a thick mix of cold acrylic and seat to place. Add a new and thinner mix externally at the contact areas, and flood this with monomer. Allow the acrylic to set, remove the splint, and cement it with temporary cement (Fig. 3). The acrylic is confined to the occlusal thirds of the shells for the purpose of splinting only, since it is unnecessary to cover the whole tooth.

Where it is necessary to restore a missing posterior tooth for a splinting effect, cut a stock acrylic tooth or a previously set bar of acrylic to the size that will make contact with the excess acrylic from the holes in the shell crowns. Add acrylic externally, and saturate it with monomer to assure a good chemical union (Fig. 4).

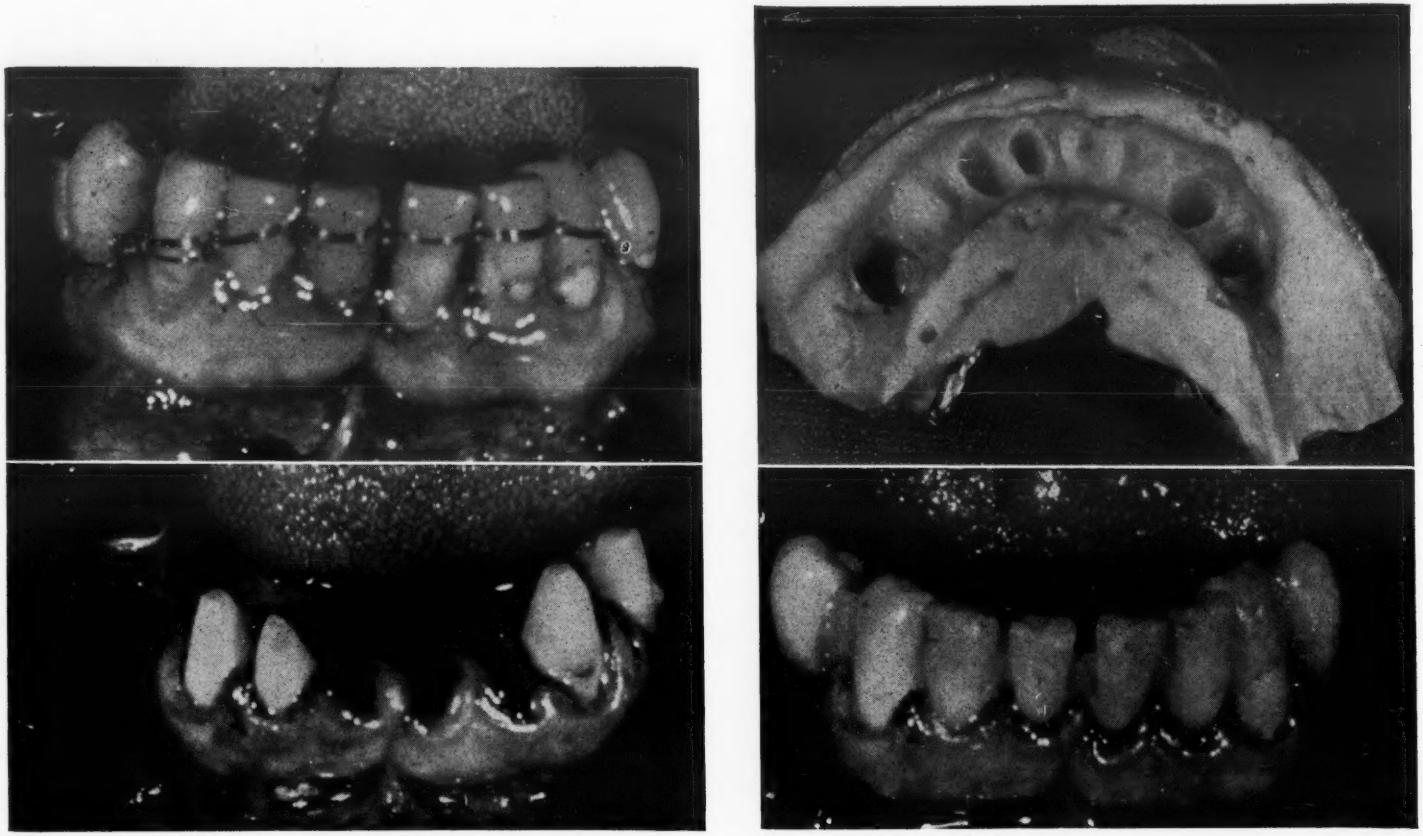


Fig. 5.—*A*, Several remaining lower teeth wired together temporarily. $\overline{5}|$, $\overline{1}|$, $|\overline{1}$, and $|\overline{2}$ had to be lost.
B, The areas of the extractions and the prepared abutments.
C, The set cold acrylic temporary splint in the alginate impression after its removal from the mouth.
D, The completed temporary splint. Note the exact reproduction of the patient's own teeth, and the acrylic in the interproximal spaces, where spaces previously existed between the teeth in the mouth, to assure continuous contact between the teeth.

ALGINATE FORMS

The use of the cold acrylics with an elastic material such as the alginates as an impression medium perhaps lends itself to more universal application in everyday practice than the foregoing techniques. For three reasons this technique is limited to temporary restorations with small spans which usually involve not more than three or four abutments. First, cold acrylics have a high setting shrinkage, even in the small volume used for filling cavities in teeth. With the great amount of bulk needed, shrinkage and therefore distortion are difficult to control. Second, since the teeth are all prepared at the same time, proper lining up of the involved teeth with no undercuts or paralleling interferences is absolutely essential. Otherwise the bridge or splint will become locked in place and impossible to remove intact from the mouth. Third, although using a single body color is acceptable, it is not ideal esthetically. Surface-staining acrylics are available and do help in some measure. Before any operative procedures are begun make an alginate impression of the involved teeth, including in it a few additional teeth as stops. A few cubic centimeters of any 1 per cent water-soluble vegetable dye is used as part of the water ratio when mixing the alginate for this impression. This is to provide for contrast between this impression and the acrylic which will be filled into the impression, as described below. Immediately place the impression in a humidor, not in water. Water will not only harden the alginate to interfere later with proper reseating but will cause dimensional changes and act as an undesirable separator between the alginate mold and the acrylic during the trial pack stage. Prepare the abutments, eliminating all interferences, extract any condemned teeth, and lubricate each preparation with petrolatum (Fig. 5). Then remove the alginate impression from the humidor. Wherever there is a previously edentulous area to be restored in addition to the newly extracted teeth, cut out a block of the algniate with Bard-Parker blade. Extend the block into the impressions of the adjacent abutments. This block will be filled in with acrylic which will be carved anatomically later. Also cut out any alginate between the impression of all proximating abutments to assure uninterrupted contact. Make a thick, wet mix of cold acrylic of the shade of choice and, starting at one end, tamp or vibrate it piece by piece into the areas to be restored. Be careful not to trap air in the acrylic as it is packed in the impression. Seat the impression in the mouth for a trial pack. The acrylic material takes the place of the cut-away tooth structure and the missing teeth. Remove the impression and the acrylic while the acrylic is in the early rubbery-set stage, and examine the acrylic. The contrast of the acrylic against the dyed alginate facilitates this examination. Trim the excess at the terminal ends of the bridge where the acrylic may have become locked and thereby may be pulled and distorted by an undercut formed by the adjacent contact embrasures. Deficiencies of acrylic are revealed by the lack of excessive fins over the gingival contours. If it is necessary to add to an abutment area, be sure to relubricate that preparation. Reseat the impression with the partially cured acrylic in the mouth, and hold it firmly until the acrylic sets. As a precaution against interferences, it is well to tease off, or loosen, the tray and its contents a few millimeters, then reseat and release it again. Repeat this pro-

cedure a few times before the final set. Upon removal of the tray after the final set, the bridge may or may not come out with the impression. In either case, remove the bridge and trim the excess. Check the occlusion and recarve where necessary, and polish. Before setting the bridge with temporary cement, ream out the inside of each crown with a No. 6 or No. 8 round bur, if necessary, until the bridge goes on and off the preparations freely without undue binding. In some cases where retention is poor, a reline of the abutment crowns may be necessary.

If one is reluctant to carry out this procedure directly in the mouth, an alternate method is to make an alginate impression of the completed preparations, including the necessary stops. Pour a cast of a hard stone in this impression. Separate the cast after ten minutes, and lubricate the abutments on the stone cast. The same technique is used on the stone cast as was described for use directly in the mouth. Before proceeding, check the seating of the alginate, cutting away any excess alginate which may interfere with the proper seating of the impression.

The alginate technique, as may readily be seen, is particularly indicated for the temporary restoration of a crown or tooth which is acting as a removable bridge retainer, with a lug and clasp around it. The acrylic replacement, being an exact reproduction of the abutment, allows the proper reseating of the partial denture.

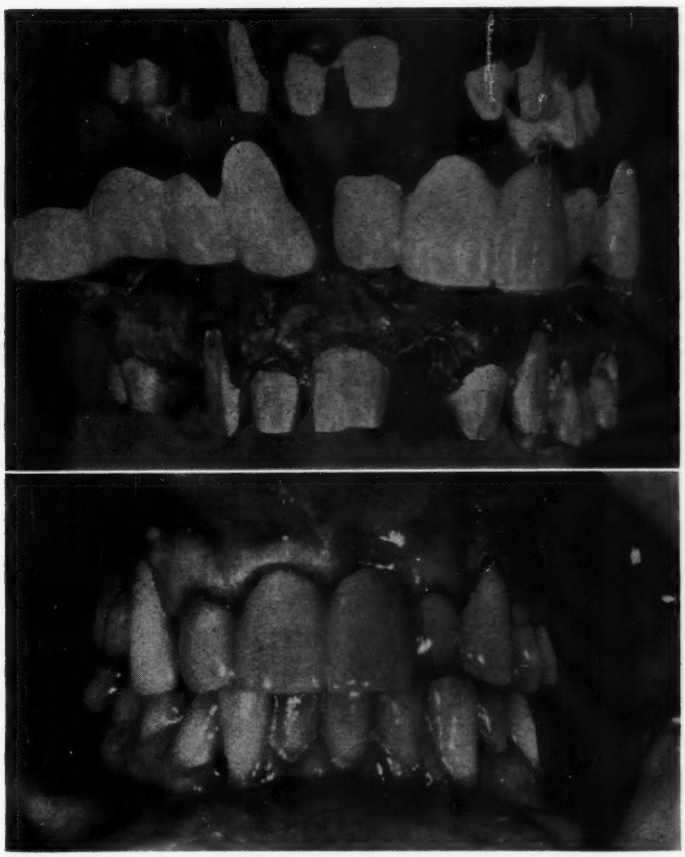
This technique is also advantageous for use in conjunction with the hydrocolloid technique. After making the preparations, tie a kite string around the neck of each tooth, gently push the string under the gingivae, and allow it to remain for a few minutes. Just before inserting the alginate impression with the acrylic packed in it, remove the kite string. The acrylic will be forced passively under the gingivae without any overextension. When the patient returns for the hydrocolloid impression, all margins of the prepared teeth will be adequately exposed upon removal of the temporary restoration. The technique is also indicated for the temporary replacement of old fixed and removable appliances which are to be replaced by fixed bridgework.

TEMPORARY RESTORATIONS WITH HEAT-CURED PLASTICS

Heat-cured plastics may be employed for temporary restorations in various ways. By citing particular cases, we can best illustrate some of the possible procedures. If a patient presents with two malaligned upper central incisors to be extracted and replaced with a fixed bridge which requires the use of double abutments of the lateral and cuspid teeth on both sides, two approaches to the problem are possible.

Prepare each abutment in one or several visits, and cover each preparation with a temporary acrylic crown form. Make an alginate impression of the completed preparations and the untouched central incisors, and pour it in a hard stone. Remove the central incisors from the cast, flush with the ridge. Wax the abutment restorations and pontics; process and polish the temporary bridge. Then extract the central incisors and insert the bridge.

Another modification of the technique is to make an alginate impression at the very first visit, before any operative procedures are done. Pour a cast in the impression in a hard stone, and dismiss the patient. On the cast itself, make the preparations, removing less structure on each stone abutment than will be removed in the mouth to assure no interference with the seating of the temporary bridge, and remove condemned teeth from the cast (Fig. 6). After completing the acrylic procedures on the prepared cast in the laboratory, make the preparations in the mouth, reducing each tooth more than it was reduced on the cast, extract the central incisors, and seat the bridge, which may be quite loose.



A.

B.

Fig. 6.—*A*, The lower cast is the one upon which the preparations for the temporary splint were made. The upper is a cast from an alginate impression of the preparations in the mouth after they had been completed. Note the smaller preparations on the corresponding teeth on the upper cast.

B, The acrylic bridges in place after they have been relined.

Three factors serve to guide the placement of the temporary bridge. There being no positive stops in this particular illustration, the contact of the central incisors with the ridge, occlusion, and the contact at both extremities determine its position. Once the position is determined, each abutment is relined with a thin mix of cold acrylic. Place the acrylic in the abutments, seat the bridge on the previously lubricated teeth, and allow the acrylic to set. Remove the bridge, trim the excess,

ream out the abutments intracoronally, if necessary, and then cement it with temporary cement. With either of these two techniques, refinements and impressions of each abutment may be made at both the dentist's and the patient's convenience. They are particularly applicable where a lapse of time is needed to allow for the complete healing and shrinkage of the extracted areas.

Another illustration concerns the case of splinting of several remaining lower teeth. The entire arch is involved, with the patient already wearing a lower removable appliance to supply the missing teeth. Carry out the gross preparation of each unclasped tooth individually so as not to interfere with the comfort and function of the partial denture. Then make an alginate impression of the prepared abutments and the unprepared clasped teeth, without the partial denture in place. The unprepared teeth act as stops to maintain the interdental relationship.

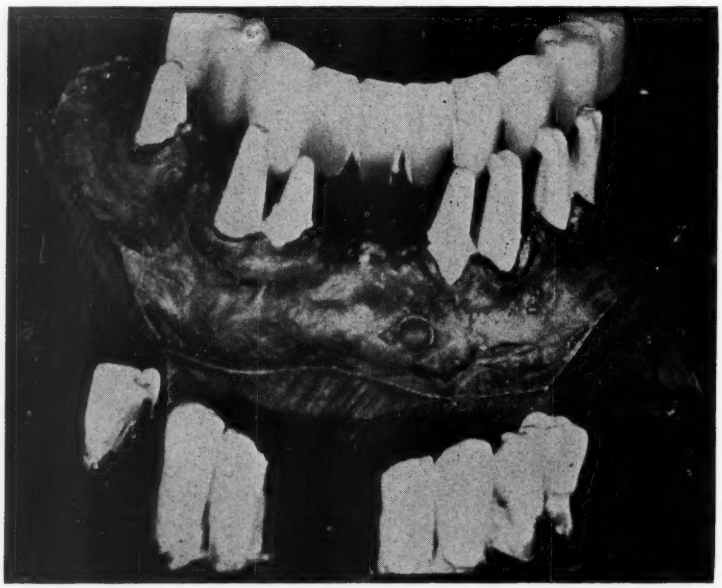


Fig. 7.—The lower cast shows several lower teeth before their preparation. The upper cast shows the prepared teeth and the acrylic splint for which it was constructed.

After occluding the casts on an articulator, prepare the remaining abutments on the stone cast, removing less structure than will be removed later in the mouth. Incorporate missing teeth or teeth to be extracted as part of the splint. After finishing the entire temporary restoration on the cast, prepare the clasped teeth in the mouth, and extract the condemned teeth as planned. Ream out the intracoronal portions of the temporary crowns for each previously prepared abutment to make certain there is no binding. Be sure to avoid cutting away from the incisal or occlusal thirds of these crowns so as not to disturb interdental relationship. Then add small amounts of thinly mixed cold acrylic to the intracoronal occlusal portions of the crowns which were made on the abutments that were prepared on the stone cast. This is done to correct the difference in the preparations on the cast and in the

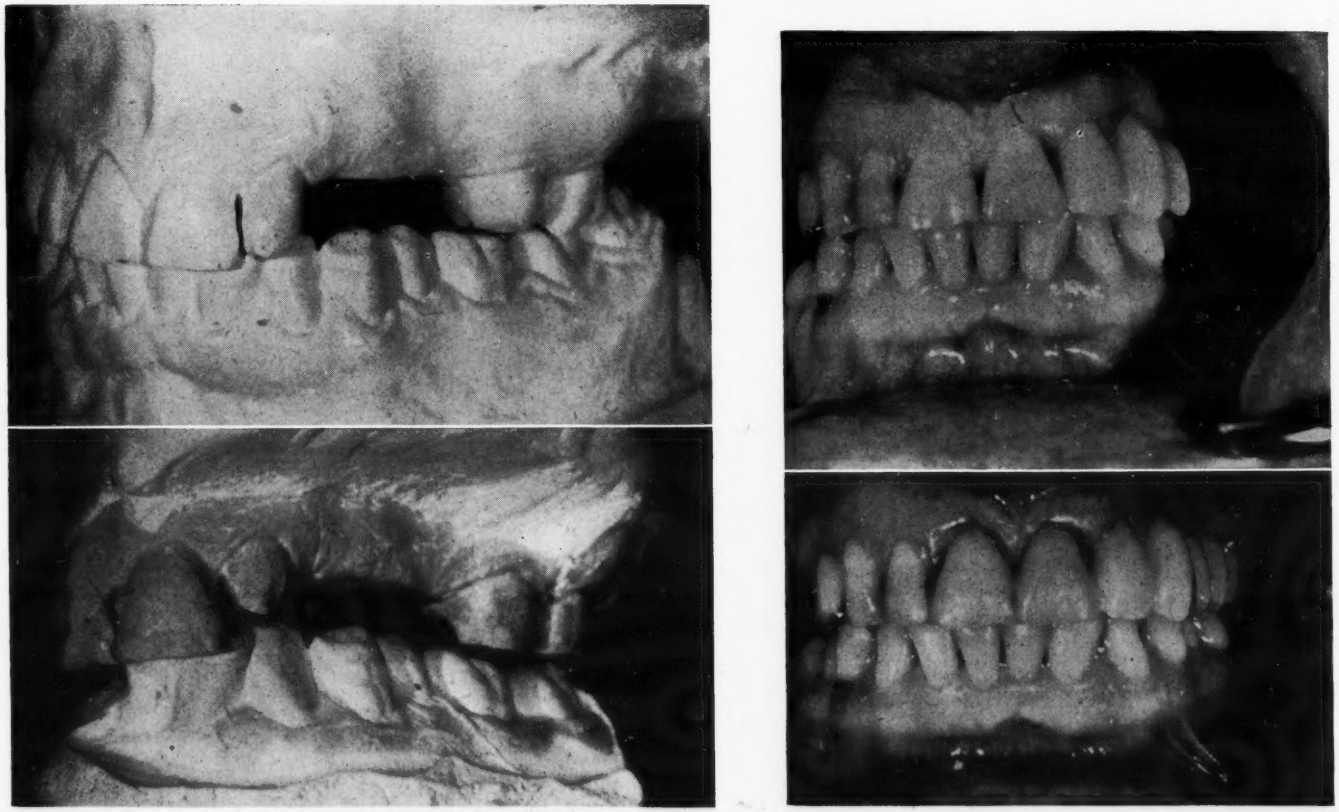


Fig. 8.—*A*, The stone cast articulated before restoring 1| to |7.
B, |2, |6, and |7 on the cast prepared for the heat-cured section.
C, The relined heat-cured section in position.
D, Both the cold-cured 1|1 and heat-cured |2 to |7 restorations sealed together.

mouth as previously planned. It is important to confine the reline of these crowns to the occlusal or incisal areas only, so as to maintain a loose fit at the gingival areas. The more abutments in a splint, the more difficult is its removal after temporarily cementing it; hence, the necessary looseness of fit.

If the operator prefers to complete all preparations at one sitting, he need only to take a wax occlusal relation before preparing the last two abutments (one on either side of the arch to maintain the interdental relations), then complete these preparations. Make an alginate impression, pour a cast in a hard stone, separate the cast, articulate, wax up, process, and polish the restoration. By this procedure it can be done all in one day, within a matter of several hours from the time of making the impression to the cementation (Fig. 7). It is important that the splint be adjusted so no binding exists before the temporary cementation.

Fig. 8, *A*, shows a case where both cold- and heat-treated acrylics were used to advantage. The stone cast preparation technique facilitated the construction from $\overline{|2}$ to $\overline{|67}$ supplying $\overline{|345}$ (Fig. 8, *B* and *C*). After its completion and insertion $\overline{1|1}$ were constructed by the alginate (cold acrylic technique—Fig. 8, *D*). $\overline{|1}$ was then sealed to $\overline{|2}$ with a thin mix of cold acrylic, resulting in a splinting effect from $\overline{1|}$ to $\overline{|7}$.

There are perhaps many other possible combinations or slight variations of these techniques. Cold- and heat-cured acrylics offer seemingly endless possibilities. These materials have even a brighter future. As quality and ease of manipulation improve, so will techniques for temporary and even permanent procedures in fixed bridgework and splinting also improve.

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RELINING FULL UPPER AND LOWER DENTURES

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THE TECHNIQUE of rebasing or relining of full upper and lower dentures is just as exacting a procedure as their original construction. It involves rebuilding the dentures, with the added factor of correcting any changes in the vertical dimension which have occured after they were inserted originally. Since once the vertical dimension is re-established, and the necessity of maintaining it is paramount, I chose this method, although some pressure is introduced; the results justify its use.

The dentures are first checked for any peripheral overextension. A moldable plastic is used for forming a peripheral functional extension on the labial, buccal, and lingual borders of the dentures, so the periphery of each denture is cut 2 mm. short of the reflection.

To remove as much pressure as possible during the making of the ridge part of the impressions, a hole about the size of a No. 12 round bur is made over the rugae area on the upper denture, and several smaller holes are made with a No. 5 round bur on the lateral sides of the labial, buccal, and lingual portions of the lower denture.

Both impressions are then made under one central point of bearing. The central bearing point is located by equalizing the pressure on the ridges. The point thus ascertained is at the center of tissue resistance. Centric and eccentric jaw positions are then recorded by the methods called to our attention by Stansbery[1].

PROCEDURE

The posterior teeth of the lower denture are removed before any other technical steps are taken, because changes occurring in the vertical dimension are the rule rather than the exception. All undercuts on the impression surface are eliminated. Flat plates are then attached to both the upper and lower dentures by means of modeling compound. These plates are placed across the palate of the upper denture and over the tongue space of the lower denture (Figs. 1 and 2). The lower plate differs from the upper in that it has a central bearing point which may be moved laterally and anteroposteriorly to locate the center of tissue resistance, and up and down to establish the required vertical dimension. In order to record Gothic arch tracings, specially-made extraoral forks which carry a stylus arm for the upper denture and a platform for the lower denture are attached to the buccal and labial aspects of the dentures (Figs. 3 and 4).

Read before the Academy of Denture Prosthetics, New Orleans, La., March 20, 1952.
Received for publication April 9, 1952.

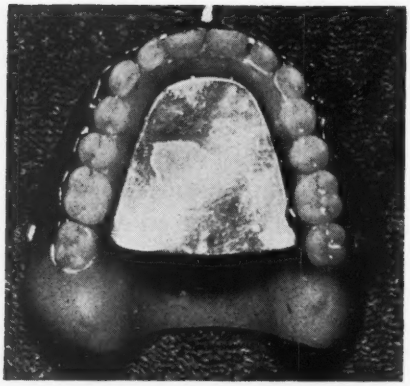

Fig. 1.

Fig. 2.

Fig. 1.—The central bearing plate attached to the upper denture.
Fig. 2.—The central bearing plate with the movable and adjustable central bearing point attached to the lower denture.

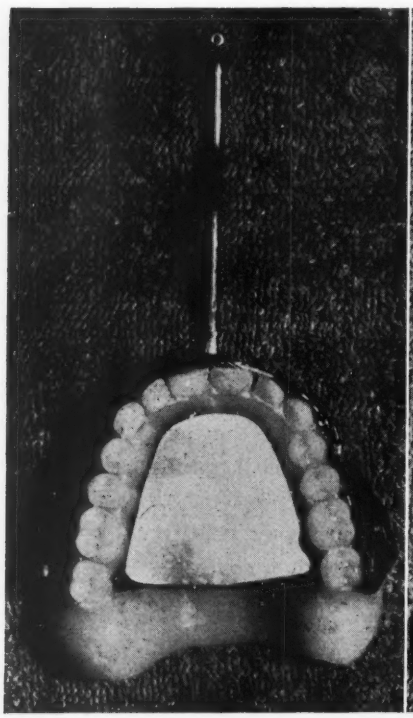

Fig. 3.

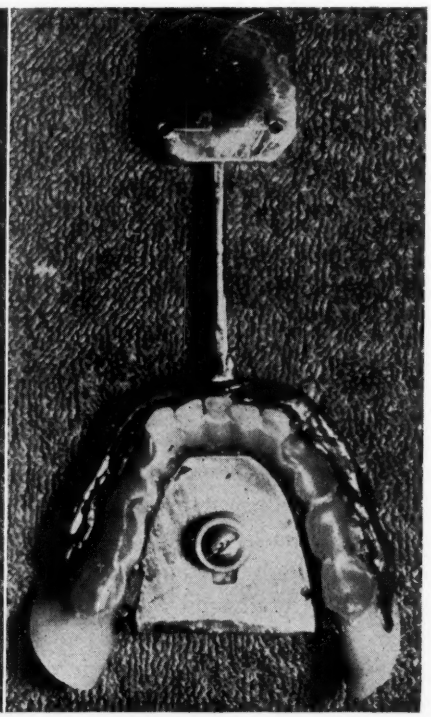

Fig. 4.

Fig. 3.—The stylus arm attached to the upper denture.
Fig. 4.—The tracing platform attached to the lower denture.

After the vertical dimension is established, and noninterference of the anterior teeth has been checked, the central bearing point is located in the following manner. A 17-gauge wire is placed in the upper stylus arm, and another 17-gauge wire is attached to the lower platform by means of an interlocking plate. While the operator is standing to the side of the patient, he asks the patient first to apply light pressure and then biting pressure. The object is to have the two wires remain parallel (Fig. 5). This is an indication that the denture bases are exerting an even pressure on the ridges. If the central bearing point has been placed too far back, the wires will converge above when pressure is applied by the

Fig. 5.—The 17-gauge wires attached to the tracing platform and stylus arm for determining the location of the central bearing point.

patient. If the central bearing point has been placed too far forward, the result will be a divergence of the rods, when pressure is applied. The central bearing point is moved anteriorly or posteriorly (as indicated by the converging or diverging of the wires) until it is located at the point where the wires remain parallel, even with varying amounts of pressure. A similar procedure is followed to locate the central bearing point in its proper side-to-side relation. The operator stands in front of the patient, and he lines up the wires. The central bearing point is moved laterally, to the right or left as indicated, until the wires remain in the same plane as each other when pressure is applied. Once the wires remain parallel when they are observed from the anterior and lateral positions, the central point of bearing is properly located, and wash impressions of the horizontal parts of the ridges of both jaws may be made under conditions of equalized pressure.

THE IMPRESSIONS

A thin mix of a zinc oxide-eugenol paste is placed in the upper denture to completely cover the ridge portion of the impression surface of the denture, except on the inner labial surface. This is left free of the impression material, as suggested by Hardy,[2] in order to avoid anterior displacement of the denture. The upper denture is then placed in the mouth, and the patient is instructed to retrude the mandible and close. The lower denture is kept in position in the mouth the whole time. When the impression material in the upper denture has set, the same procedure is employed for the lower impression. The upper denture is kept in the mouth and the impression paste is placed in the lower denture. However, the entire surface of the lower denture is covered with the impression material. No problem of anterior shifting exists in the lower denture. When the impression material in the lower denture is set, the impressions of the horizontal parts of the ridges are complete. The peripheral borders of the impressions are to be formed later (Figs. 6 and 7).

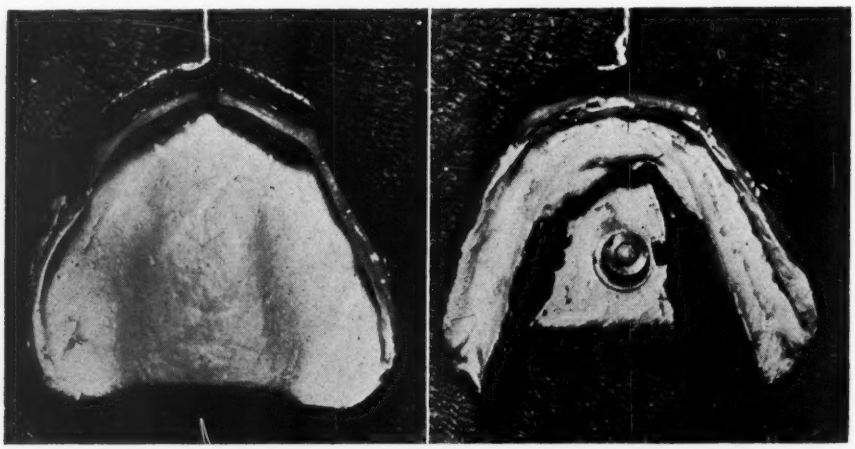

Fig. 6. Fig. 7.

Fig. 6.—The impression of the ridge surface of the upper denture.
Fig. 7.—The impression of the ridge surface of the lower denture.

JAW RELATION RECORDS

A slight opening in the vertical dimension may have occurred by the introduction of the zinc oxide and eugenol paste. So, the vertical dimension is rechecked and corrected if necessary.

Centric, protrusive, and lateral jaw position records are then made by utilizing the Gothic arch tracing. It must be stressed that in this procedure, the tracing is made with the central bearing point at the center of tissue resistance. Under these conditions it is extremely accurate.

The patient is instructed to execute his protrusive and lateral jaw excursions until a Gothic arch tracing with a sharp apex is produced (Fig. 8).

The centric record is made while the dentures are under swallowing pressure. With the stylus at the apex of the Gothic arch tracing, fast-setting plaster is injected between the upper and lower bearing plates. Lateral and protrusive check bites are registered in the same manner. However, since 45 degree teeth are used in this technique, the central bearing screw is raised 1.5 mm. while the protrusive and lateral excursions are recorded (Fig. 9). The point at which the lateral

Fig. 8.

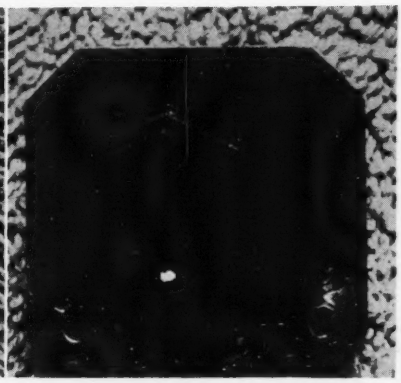

Fig. 9.

Fig. 8.—The Gothic arch tracing.

Fig. 9.—The double Gothic arch tracing. The posterior tracing is made at the level of the vertical dimension of occlusion. The anterior tracing is made with the central bearing screw raised 1.5 mm. The marks on the arcs of the anterior tracing indicate the points at which the lateral check bites are made.

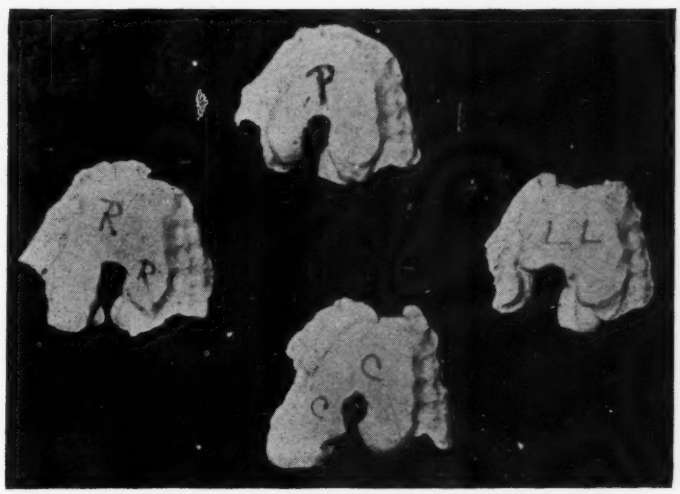

Fig. 10.—The four check bites.

plaster check bites are made is 6 mm. out on the arcs of the tracing from the apex which indicates centric position. This measurement is necessary because the lateral masticatory stroke in the first molar region is about 3 mm., and the extraoral tracing device extends forward twice the distance from the condyle to the first molar tooth. After completing the plaster check bites (Fig. 10), which by their forms are automatically indexed to the lingual portions of the dentures, the peripheral borders of the impressions are completed.

FORMING THE PERIPHERIES

Since the first impressions of the horizontal areas of the ridges act as stabilizers and permit no change in the relationship of the dentures, the central bearing plates and the tracing devices are now removed from them. This will permit freedom of movement of all tissues around the dentures. A moldable plastic material is painted on the periphery of the upper denture. It is muscle-trimmed by instructing the patient to go through the motions of puckering and grinning. This produces well-defined functional borders (Fig. 11).

After the upper impression is completed, the moldable plastic material is painted on the borders of the lower denture. Special attention is given to the muscle-trimming of the lower denture to make sure that the borders in the region of the masseter muscle and the floor of the mouth are anatomically well-trimmed so that the denture will not be dislodged in function. These two areas are the causes of many popping dentures. To trim for the masseter muscle, a downward force is applied to the denture while the patient closes against this pressure, besides the puckering and grinning motions which the patient makes. The patient is also instructed to open the mouth wide to limit the denture border at the distolingual occlusal end. This stretches the pterygomandibular raphe against the denture.

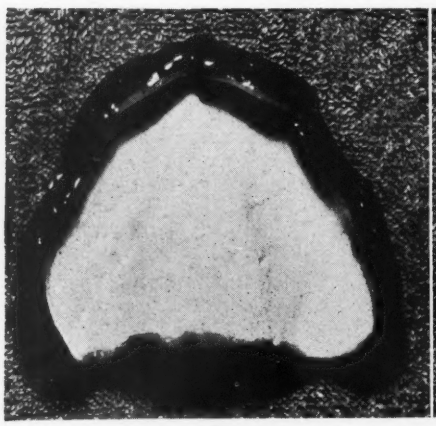

Fig. 11.

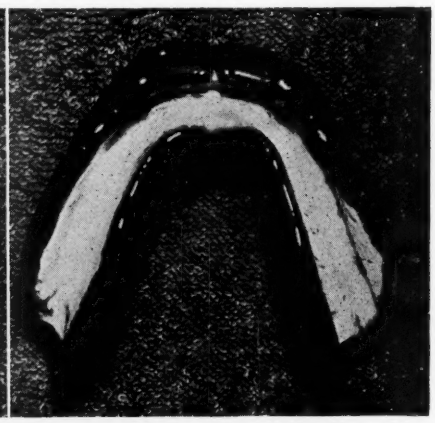

Fig. 12.

Fig. 11—The completed upper impression.
Fig. 12.—The completed lower impression.

To trim the lingual borders, the patient is instructed to place the tongue forcibly into each cheek several times. This action will develop the correct thickness, as well as the proper amount of anatomic relief to the tissues buccal to the lingual flange, from the most posterior distolingual turn to the area lingual to the first bicuspid. It will provide sufficient freedom of movement of these tissues for the functional purposes of the denture (Fig. 12).

Fig. 13.

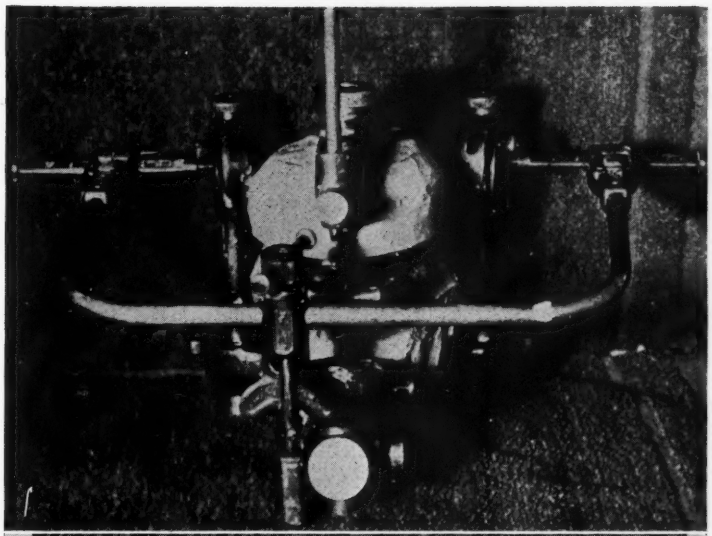

Fig. 14.

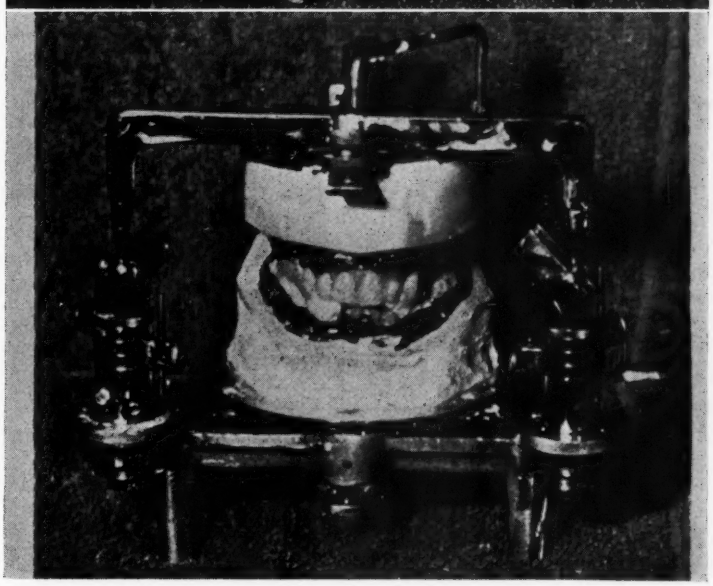

Fig. 13.—The dentures mounted on a Hanau Model H articulator.
Fig. 14.—The dentures mounted on a Stansbery Denture Tripod.

ARTICULATOR ADJUSTMENT

Either an adjustable articulator or the Stansbery Denture Tripod may then be used (Figs. 13 and 14). If an adjustable instrument is to be used, a face-bow record is made to the instrument before the casts are poured.

The casts are then poured and indexed. If the Tripod is used, all the check bites, (centric, protrusive, and lateral) are utilized. The lateral check bites are not used in other adjustable articulators because the limitations of these instruments will not permit their use with any degree of accuracy.

The posterior teeth are reset and the occlusion is balanced. Then the dentures are invested, packed, processed, and returned to the articulator, where the teeth are milled into fine occlusal balance.

This procedure may seem quite extensive for a relining technique. Nevertheless, if the procedure is to be successful, all the factors involved in making the original dentures must be considered. Otherwise, detrimental effects as far as esthetics, preservation of the ridges, and masticatory ability with comfort will ensue.

REFERENCES

1. Stansbery, C. J.: Functional Position Checkbite Technic, J.A.D.A. **16**:421-440, 1929.
2. Hardy, I. R.: Rebasing the Maxillary Denture, D. Digest **55**:23-27, 1949.

85 West St.
Danbury, Conn.

The Readers' Round Table

Pratt, Kansas

Editor, Journal of Prosthetic Dentistry,

Your comments regarding the adjustments of my articulator (J. PROS. DEN. **2**:288, 1952) indicate a misinterpretation on your part which was due to an omission from the description of the adjustments of the instrument on p. 375.

The condylar guidances are adjustable individually from the tracing made on the sagittal marker. The formula mentioned refers to the adjustment of the incisal table and is correctly described on pp. 375-376.

The milling machine has identical adjustments of the condylar guidances with those on the articulator. These are in the same relative position and are adjusted to the same angulation as the condylar guidance on the articulator.

The incisal guide table is not included in the milling machine because the cusp inclinations and vertical and horizontal overlap of the anterior teeth furnish the same incisal guidance as they do in the mouth.

I would appreciate it if you would clarify these points in an early issue of the JOURNAL.

Yours very truly,
J. E. Scott, D.D.S.

We are most happy to give Dr. J. E. Scott an opportunity to supply the additional information about his articulator and milling device. Our criticism of the instruments was based upon the information in the article as it was submitted. This criticism was not valid in the light of this additional information.

Ed.

News and Notes

ANNOUNCEMENTS

The Twenty-eighth Annual Greater New York Dental Meeting will be held on Dec. 8-11, 1952, at the Hotel Statler, New York, N. Y.

The American Board of Prosthodontics will hold its next examination at the School of Dentistry, University of Indiana, 1121 West Michigan Street, Indianapolis 2, Ind., February 1-7, 1953. For further information write to Dr. Irving R. Hardy, Tufts College Dental School, Boston, Mass.

Tufts College Dental School announces several prosthetic post-graduate courses to be offered throughout the academic year of 1952 and 1953. The courses to be presented are: Full Denture Prosthesis, Dr. Irving Hardy and staff; Immediate Upper and Partial Lower Denture Prosthesis, Dr. Irving Hardy and staff; Occlusal Rehabilitation, Dr. Louis Alexander Cohn; Crown and Bridge Prosthesis, Drs. L. Walter Brown and Phillip Williams; Precision Prosthesis in Functional Treatment, Dr. Ernest Granger and staff; Tooth Construction and Staining, Dr. Frank Eich; and Construction of a Full Upper and Lower Denture on the Stansbery Denture Tripod, Dr. Jack Buchman. Further information may be obtained by writing to the Director of Postgraduate Studies, Tufts College Dental School, 136 Harrison Avenue, Boston, Mass.

The Twenty-first Annual Postgraduate Clinic of the District of Columbia Dental Society will be held March 15-18, 1953, at the Shoreham Hotel, Washington, D. C. The General Chairman is Dr. Z. Bernard Lloyd, 2007 R Street, N. W., Washington, D. C. Further information can be obtained by writing to Edward H. Steinberg, Executive Secretary, 1835 Eye Street, N. W., Washington 6, D. C.